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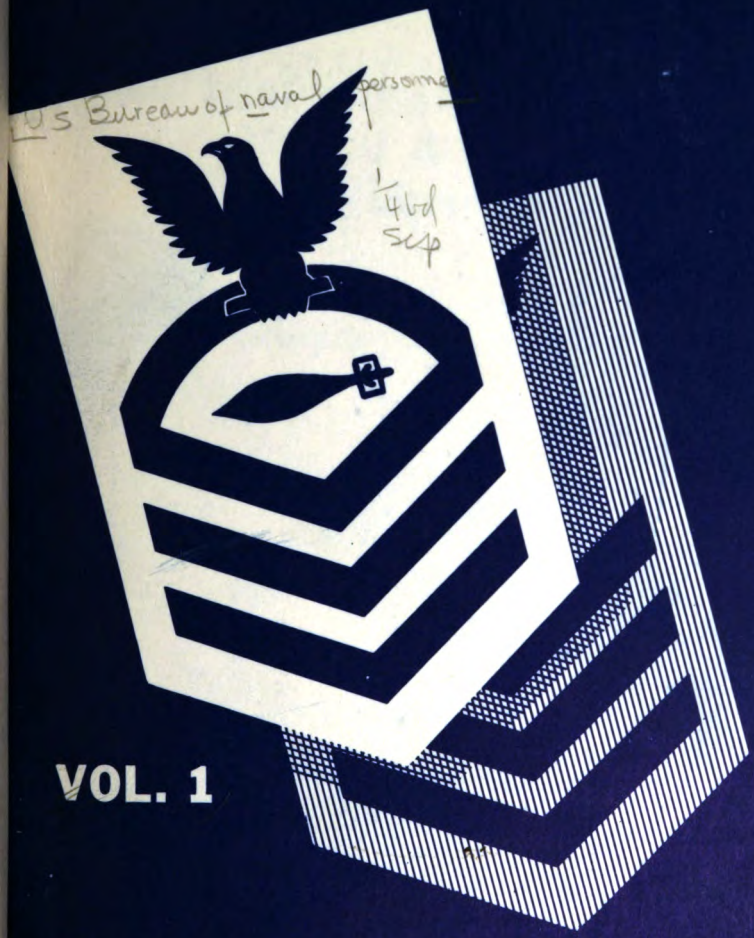

VOL. 1

TORPEDOMAN'S MATE 1 & C

NAVY TRAINING COURSES

NAVPERS 10157-B

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TORPEDOMAN'S MATE 1 & C Volume 1

Prepared by U.S.

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

NAVPERS 10157-B

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1959

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E–2 or 8 mos. total service.	6 mos. as E–3 or 14 mos. total service.	12 mos. as E–4.	12 mos. as E–5; total service at least 36 mos.	36 mos as E–6.
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E–3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

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INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.
	12	9 mos.	15 mos.	21 mos.	24 mos.	36 mos.	42 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.
DRILLS ATTENDED IN GRADE#	48	27	27	45	54	72	108
	24	16	16	27	32	42	64
	12	8	13	18	20	32	38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48	14 days	14 days	14 days	14 days	28 days	42 days
	12	14 days	14 days	14 days	28 days	42 days	42 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

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PREFACE

This is volume 1 of a two-volume training course. This course was written for men of the Navy and Naval Reserve who are studying for advancement to the rate of Torpedoman's Mate First Class or Chief. When supplemented by further practical experience in the maintenance and repair of torpedoes, and in supervision of those operations, it will help the Torpedoman's Mate to meet the qualifications for advancement in rating. The qualifications for advancement in rating are listed in appendix II of this volume.

This volume is intended primarily for use in reviewing the principles of air-steam and conventional electric torpedoes, firing and recovery procedures, gyros and exploders, and torpedo fire control. Chapter 2 discusses supplies, records, and reports. Chapter 9 is an introduction to the maintenance of electric and electronic torpedo circuits. Volume 2 of this course will describe chemical and homing torpedoes, and influence exploders.

This book is one of a series of Navy Training Courses. It was prepared for the Bureau of Naval Personnel by the U. S. Navy Training Publications Center, Washington 25, D. C. The Center is indebted to personnel of the Bureau of Ordnance who checked the manuscript for technical accuracy.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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TORPEDOMAN'S MATE
1 & C
Volume 1

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CHAPTER 1

INTRODUCTION

The United States Navy is not the same as it was when you first enlisted. It's not the same as it was last year. Or last week, for that matter. Things are changing fast.

The Navy has made changes before. It changed from sail power to steam, and from ships of wood to ships of steel. It changed from muzzle-loading smooth bores to breech-loading rifled guns. But all of these changes were small and slow compared to the ones you're seeing now.

In your time the Navy has commissioned entirely new classes of ships: the frigate, the guided missile cruiser, the guided missile destroyer, and the nuclear-powered submarine. Several kinds of guided missiles and homing torpedoes have become operational since you first enlisted. We think this is only the beginning; future developments in electronics and nuclear science will make our ships and weapons of today look primitive.

Because of these rapid changes, the Navy's technical ratings, such as yours, are changing too. There are new torpedoes and new firing methods to learn about; and, as we have said, you've seen only the beginning. If you're the type who likes a routine job that stays the same day after day, all this change is a nuisance. But some men are never satisfied with things as they are. They want to see things advance and improve, and they get actual

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pleasure from learning something new. We hope you are one of these men. If you are, you can have a satisfying career as a technical specialist in the Navy.

WHAT THIS COURSE IS ABOUT

If you are a TM2, this course is intended to help you prepare for advancement to TM1. If you're a TM1, it should help you prepare for advancement to TMC. The course is in two volumes. This one, Volume 1, tells you some things you should already know. It's a review. We have a good reason for that. As a TM2 or TM1, you have probably been a specialist. This is especially true if you've served on a repair ship or tender. You've probably specialized in one part of the torpedo; if so you may have lost touch with the rest of it. You may have had one or several types of duty, but we're sure you have not occupied all the billets available to Torpedoman's Mates.

As you advance in rating you will have more and more men under your supervision. If you want your men to do the best work they're capable of, you'll have to know their jobs even better than they do. Without losing any skill in your specialty, it would be a good idea for you to review all of the torpedo, and all types of work associated with its maintenance, repair, and firing. If this review volume seems like old stuff to you, so much the better. It will be fast reading.

Volume 2 deals with things that may be entirely new to you. It discusses chemical torpedoes and electric setting mechanisms, and describes all the types of homing torpedoes now in the Fleet. But we suggest that you study this volume first. If you find a subject on which you need a more thorough review, look it up in the course *Torpedoman's Mate 3 & 2*, Volume 1, NavPers 10155, and Volume 2, NavPers 10156, or in the OP's listed in that course.

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Content of this Volume

This chapter discusses the various types of assignments open to Torpedoman's Mates, so you'll have an idea of what your future may be like.

As a TM1 or TMC, you will have a larger share of the Navy's administration and paper work. Chapter 2 discusses the Navy supply system, and lists some of the forms and reports you will make out, or at least supply the basic information for. Chapter 3 is a review of the air-steam torpedo as a whole, just in case you've specialized so thoroughly that you've lost sight of the whole picture. Chapter 4 reviews the various methods of torpedo firing, and the recovery of exercise torpedoes.

Chapter 5 is about torpedo fire control. This chapter briefly reviews what you learned about fire control in *Torpedoman's Mate 3 & 2*, and then goes into more detail on several points that will be important to you as a TM1 or TMC. Chapter 6 deals with gyros. We assume that you're very familiar with the torpedo gyro and what it does. Chapter 6 takes you deeper into some of its basic principles, and introduces the subjects of gyro maintenance and overhaul.

In chapter 7 we will review the various types of contact exploder mechanisms, and introduce some principles of exploder mechanism overhaul. (You'll find information on the influence types in Volume 2.)

Chapter 8 is a review of the electric torpedo, with emphasis on the Mk 18 Mod 2. Chapter 9 is an introduction to the maintenance and repair of electric and electronic torpedoes. It describes the various uses and applications of electricity and electronics in current torpedoes. It summarizes your qualifications for advancement in rating, insofar as they deal with electricity, and gives you some suggestions for meeting them.

Study Guide

As you know, this book is intended for men of two different rates: TM2 preparing to advance to TM1, and

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TM1 preparing to advance to TMC. But we haven't found it practicable to divide the book into two separate parts, one for each rate. In most chapters you'll find information that applies to both rates. Take chapter 6, on gyros, for example. A TM1 is required to know the construction of the gyro and its housing. The TMC is required to adjust it and perform authorized repairs. We suggest that you read all chapters, no matter which rate you're preparing for. Your qualifications for advancement in rating (Appendix II of this volume) will show you which subjects you should give special study. There's one exception. If you're preparing for TM1, and if you're in a rush, you can skim chapter 7 lightly or skip it altogether.

This course is also intended to help Naval reservists advance in the emergency service ratings TMT and TME. If you're a TMT, you can skip chapters 8 and 9. If you're a TME, you can skip chapters 3 and 5. The following table is a summary:

Chapter	TM	TMT	TME
1	1,C	1,C	1,C
2	1,C	1,C	1,C
3	1,C	1,C	.....
4	1,C	1,C	1,C
5	1,C	1,C	.....
6	1,C	1,C	1,C
7	C	C	C
8	1,C	.....	1,C
9	1,C	.....	1,C

DUTIES AND ASSIGNMENTS

Your type of duty depends largely on the type of ship or station to which you are assigned. We won't go into great detail about any one assignment. You have already been assigned to at least one of the types of ships or activities requiring Torpedoman's Mates. But you have

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probably specialized in only one or two types of assignment. For that reason we will try to give you a brief summary of the principal assignments available to Torpedoman's Mates.

Destroyer Types

On destroyers and destroyer escorts equipped with quintuple tube mounts, (fig. 1–1), duties are usually divided as follows:

The TORPEDO-BATTERY CAPTAIN is usually a TMC. He is normally responsible for all torpedo maintenance. As petty officer-in-charge, he organizes, supervises, and performs maintenance, adjustments, and limited repairs on torpedoes and their associated equipment. His general-quarters duties include supervision of all Torpedoman's Mates and strikers in readying and training the ship's torpedo mount, and in firing the torpedoes. He must be able to estimate target angle, target speed, and range, so that torpedoes can be fired in local control at the tube mount if necessary. He must be able to take over the duties of the torpedo officer in an emergency.

The TORPEDO-MOUNT CAPTAIN is usually a TM1 or TM2. He assists in the supervision of repair and maintenance

Figure 1–1.—You may be assigned to a destroyer.

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of torpedoes. At general quarters he supervises the work of the tube trainer and the gyro setter at their stations on the mount. Like the torpedo-battery captain, he should be able to supervise firing at the tube mount if local control becomes necessary.

The TORPEDO-DIRECTOR OPERATOR may be either a first class or second class Torpedoman's Mate. He energizes the torpedo director, and trains its telescopic sight to keep it centered on the target, or he keeps the dial pointers matched to correspond with control data set into the director by the torpedo control officer. His routine duties are similar to those of the torpedo-mount captain.

The TORPEDO-DIRECTOR TALKER is usually a Torpedoman's Mate second class. He receives and transmits messages by phone on the bridge, and operates the torpedo-firing selector switches. His routine duties are the same as those of torpedo maintenance men or torpedo maintenance assistants.

The TORPEDO-TUBE TRAINER, who is also usually a TM2, assists in readying the tube mount. He trains the mount to keep the dial pointers matched in conformity with the orders transmitted by the torpedo director. He receives orders by phone from the bridge, and relays them to the torpedo-mount captain and gyro setter.

The TORPEDO-GYRO SETTER is a Torpedoman's Mate second class. He assists in readying the torpedo mount, makes ordered settings for torpedo speed and depth, and gyro angle and spread; he parallels electric firing with percussion firing. His routine duties are usually the same as those of the torpedo-director talker.

If you have served on a destroyer, you may have performed all of these duties. Or you may have specialized in only one of them. In any event, you should learn the duties of every member of your crew, so that you can take over any man's job in an emergency. On a destroyer you may have the additional job of supervising operation of the depth-charge battery. If you've had no

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experience with depth charges, we suggest that you review chapters 8 and 9 of *Torpedoman's Mate 3 & 2*, Volume 2, NavPers 10156.

Submarines

If you are stationed aboard a submarine (fig. 1–2), your duties will differ considerably from those we outlined above. The operation of submerged torpedo tubes differs from that of surface mounts; and torpedoes fired from submerged tubes are often of the electric type, with their own special maintenance and repair procedures. Fire control problems are much the same, although you can't train submerged tubes except by maneuvering the submarine. We will briefly summarize the duties usually performed by Torpedoman's Mates Chief, first class, and second class, on submarines. (A submarine has both a forward and an after torpedo room. Operations in the two torpedo rooms are practically identical.)

The TORPEDO-TUBE CAPTAIN may be a Torpedoman's Mate Chief in the forward torpedo room and a Torpedoman's Mate first class in the after room. He supervises the loading and firing of the torpedo tubes. He does many of the critical jobs himself, including

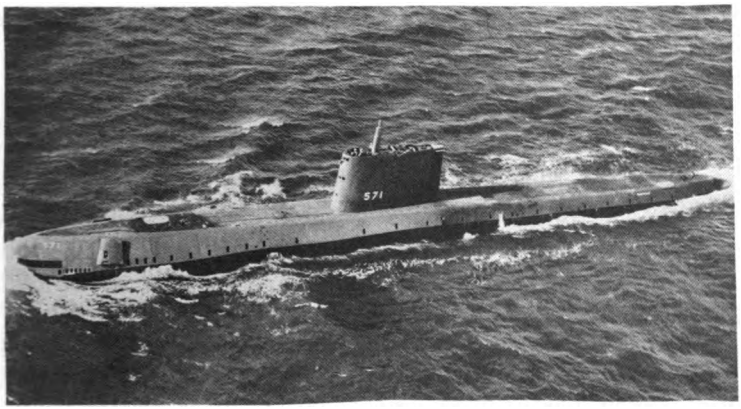

Figure 1–2.—You may be assigned to a submarine.

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operation of the torpedo-tube blow and vent manifold, the tube poppet valves, and the outer doors. He supervises preparation of both torpedoes and tubes for firing. If the only TMC aboard is chief of the boat, both torpedo rooms may be supervised by Torpedoman's Mates first class.

The GYRO SETTER is a Torpedoman's Mate second or third class. He observes the gyro settings generated by the torpedo data computer, and compares them with the torpedo gyro settings to be sure they are properly matched in automatic control. If the dials show any discrepancy, he matches the settings by hand.

The DRAIN-VALVE OPERATOR is a Torpedoman's Mate second or third class. He operates the drain valves that control the flooding and emptying of the tubes, as ordered by the tube captain. He checks impulse air pressure before the torpedoes are fired, and fills the tube firing valves after firing.

The MAN-BETWEEN-THE-TUBES is also a Torpedoman's Mate second or third class. He operates the interlock levers, the hand-firing key, and the spindle settings that control the torpedo depth, speed, and gyro angle. He checks to see that each spindle is in the proper position for firing.

The TORPEDO-RELOAD MEN may have any rating. Three to five reload men make up the remainder of the torpedo crew in each torpedo room.

PT Boats

There are only a limited number of assignments for Torpedoman's Mates aboard PT boats. The firing procedure used on PT boats differs considerably from that used on destroyers, and the firing equipment is often of a much simpler type. (See fig. 1–3.) Torpedoes are usually launched from racks instead of tubes, and the PT boat may be put on a collision course with the target to aim the torpedoes.

Aboard PT boats, only limited maintenance and

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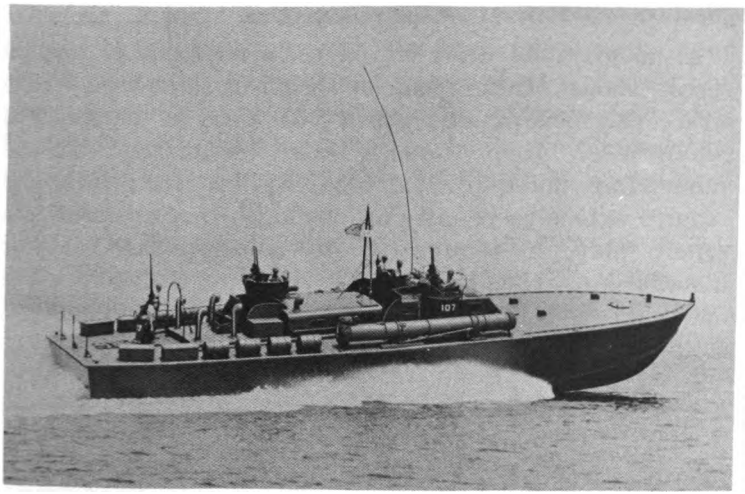

Figure 1–3.—You may be assigned to a PT boat.

readying procedures are performed on torpedoes. These procedures are carried out by Torpedoman's Mates who make the regular BuOrd check-off inspections, service the torpedoes with water, fuel, air, and oil, and make any minor repairs that may be necessary. During action they prepare the torpedoes for firing, and man the torpedo release racks.

Aviation Activities

If you are assigned to an aviation activity, you will probably be classified as an aviation torpedo mechanic. You will have no torpedo tubes to work with, and your torpedoes will be of special types designed for launching from aircraft. And of course you will fire no torpedoes; your work will end when the torpedoes are loaded in the airplane racks and made ready for launching.

Aviation torpedo mechanics make the regular BuOrd check-off inspections, service the torpedoes with fuel, water, air, and oil, make minor repairs, load torpedoes aboard airplanes, and make them ready for firing. They may also help load bombs and rockets aboard airplanes.

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Repair Activities

Although some carriers have fairly complete torpedo repair shops, other types of fighting ships rarely have either the tools or equipment you need for complicated repair jobs. Torpedoman's Mates on surface craft and submarines make limited repairs; but when torpedoes require extensive repairs or overhaul, they are sent to a repair ship, a tender, or to a shore-based repair installation. (See fig. 1–4.)

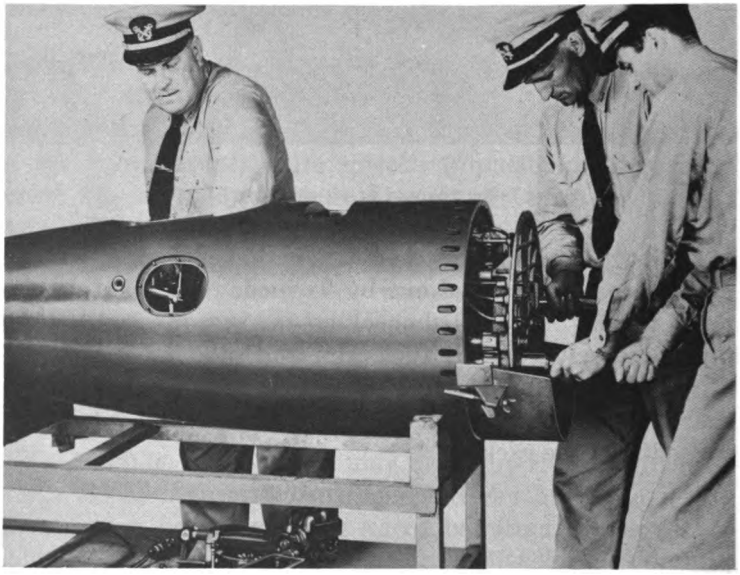

Figure 1–4.—Torpedoes are sent to repair ships for extensive repairs or overhaul.

Such repair ships and shore-based repair facilities are manned by specialized torpedo mechanics. The following are typical jobs.

TORPEDO MECHANIC, SHOP, BASIC. Performs, under close supervision, routine tests, repairs, and maintenance of electrical and mechanical torpedoes and torpedo tubes

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at repair activity: Assists in testing and maintaining torpedo tubes; makes minor repairs, adjustments, and replacements on electrical and mechanical torpedoes and other equipment; charges torpedo storage batteries; lubricates and performs other periodic maintenance on torpedoes and torpedo tubes, following Bureau of Ordnance check-off lists.

TORPEDO MECHANIC, MECHANICAL TORPEDOES, SUPERVISOR. Supervises Torpedoman's Mates in inspection, maintenance, and overhaul of chemical and air-steam torpedoes, depth charges, and mechanical parts of associated control equipment and launching mechanisms: Assigns and oversees personnel in conducting routine maintenance, preliminary and final tests, inspections and adjustments, repair and overhaul of air, surface, and submarine types of mechanical torpedoes, torpedo tubes, mounts, and depth charge release mechanisms; inspects underwater ordnance and equipment logs for accuracy and completeness of entries; trains personnel in maintaining, repairing, and overhauling torpedoes and launching mechanisms.

TORPEDO AFTERBODY TEST STAND OPERATOR. Performs final inspections and tests of afterbody components and entire afterbody after major overhaul: Tests and inspects power plants, depth and steering mechanisms, valve systems, control equipment, starting gear, and gyro mechanism; inspects gimbals for freedom of movement; takes throw readings and alters throw of rudders if necessary; maintains records of overhauling and replacements made; trains and oversees personnel in testing afterbody components.

TORPEDO AFTERBODY MECHANIC. Disassembles, cleans, inspects, and reassembles torpedo afterbodies at repair activities: Breaks down bulkhead and removes tail, main engine, gyro housing, and starting gear; cleans interior of afterbody; inspects afterbody for loose studs; examines strengthening rings, oil tanks, and exhaust stacks for defects, and afterbody shell for dents; overhauls exhaust

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valves and tail; reassembles afterbody components and tests for leaks in check and delivery valves and in reducing, control, and pilot valves; inspects starting gear; maintains records of repairs and overhauls; directs and trains personnel in the test, repair, and overhaul of valves and valve groups.

TORPEDO GYRO HOUSING REPAIRMAN. Inspects and overhauls steering engines and depth mechanisms of torpedoes: Tests, disassembles, and cleans mechanisms of electrical, chemical, and air-steam torpedoes such as vertical steering mechanisms, parts of angle firing setting mechanisms, and parts of immersion or depth control mechanisms or Uhlan gear; examines mechanisms for defects; repairs or replaces worn or broken parts; lubricates and assembles parts; tests individual mechanisms and complete units; maintains records of overhaul and replacements made; trains and oversees personnel in maintaining, overhauling, and testing gyro housing mechanisms.

TORPEDO GYRO REPAIRMAN. Overhauls and services torpedo gyros: Disassembles gyro equipment of torpedoes and inspects wheels and centers, bearings, races, balls, retainers, and inner and outer gimbals for rust, dampness, and general condition; cleans and dries unassembled parts, replaces or repairs worn or broken parts; reassembles, lubricates, and adjusts parts; reinstalls gyro equipment in housing; trains and oversees personnel in maintaining, overhauling, and testing torpedo gyros.

TORPEDO MAIN ENGINE REPAIRMAN, MECHANICAL. Tests, disassembles, and repairs mechanical torpedo main engine: Inspects and repairs parts such as main engine gear assembly, spindle casing, propeller shaft, A-frames, oil pumps, turbines, governor, and other components; reassembles main engine components; checks clearance of A-frames, turbine wheels, and propeller shaft thrust; installs turbines, estimating thickness of gaskets

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required; lubricates parts; performs rundown test on main engine assembly; maintains record of overhaul and tests; trains and oversees personnel in overhauling, testing, and maintaining mechanical torpedo main engines.

TORPEDO VALVE GROUP REPAIRMAN. Tests, repairs, and overhauls valves and valve groups including piston, rotor, poppet, and ball-type valves on electrical, chemical, and air-steam torpedoes at a repair activity: Inspects valves for mechanical defects and improper adjustments; repairs or replaces worn or broken parts; lubricates and assembles valves and valve groups; makes final tests on individual mechanisms and complete units; repairs all types of valves used on torpedoes such as check and delivery valves, reducing, control, and pilot valves; inspects and repairs starting gear; maintains records of repairs and overhauls; directs and trains personnel in the test, repair, and overhaul of valves and valve groups.

TORPEDO WAR HEAD AND EXERCISE HEAD MECHANIC. Installs, maintains, and tests torpedo war heads, exercise heads, and components at repair activity: Attaches exercise heads or war heads on electrical, chemical, and air-steam torpedoes; adjusts and overhauls exercise heads; dismantles, repairs, and assembles exploders; tests exploders on test stand by disassembling firing mechanism and base parts, testing electrical and electronic circuits, and determining impeller tension; removes exploder mechanism dummy blocks or sheet metal covers and installs exploders in war heads; maintains logs of overhauls and replacements made on exercise heads, detonators, and boosters; trains and oversees personnel in testing, maintaining, and repairing torpedo war heads and exercise heads; enforces safety precautions.

THE TORPEDO OFFICER

On fighting ships, Torpedoman's Mates are members of the gunnery department, and they are under the

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immediate supervision of the torpedo officer. On repair ships and tenders, Torpedoman's Mates are members of the repair department, and are under the supervision of the torpedo repair officer. (In *Torpedoman's Mate 3 & 2*, Volume 1, we discussed the organization of the gunnery department and the torpedo repair shop in some detail. We will not repeat that discussion here.)

You will be working with the torpedo officer, and it will be your responsibility to put his policies into effect. In an emergency, you may suddenly have to take over the duties of the torpedo officer. We will summarize those duties briefly.

On a fighting ship, the torpedo officer has a number of responsibilities. At general quarters on a destroyer, he controls the torpedo battery from the torpedo control station. He supervises operation of the torpedo director, using the captain's estimates if available, or his own. When more than one ship is firing, he makes the torpedo director setup ordered by the division commander and fires in accordance with standard doctrine (discussed in chapter 4).

On repair ships and tenders, and at repair installations, the torpedo repair officer has complete charge of all torpedo repairs. His normal duties include preparation of a torpedo repair schedule, supervising repair work, completing reports, and supervising maintenance of the repair shop and its equipment.

The torpedo officer of a fighting ship spends most of his time supervising the maintenance and repair of torpedoes and tubes, and the equipment associated with them. The repairs are limited in nature, of course, but his unit makes whatever repairs are possible with the facilities at hand.

The ROUTINE UPKEEP of torpedoes includes periodic tests, adjustments, and lubrication. The maintenance operations to be performed on each type of torpedo or equipment are listed in a specific ordnance pamphlet

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(OP). OP's give the exact steps to be followed, in the form of check-off lists. Tests and maintenance routines are always carried out according to these lists, so that no item will be forgotten. When necessary, the OP's are supplemented by other ordnance publications. The torpedo officer should have a complete set of all publications pertaining to the gear he works with. (We discussed ordnance publications, and how to get them, in chapter 1 of *Torpedoman's Mate 3 & 2,* Volume 1.)

REPAIRS, according to Navy Regulations, include "such work as may be necessary to restore the ship or article under consideration to serviceable condition without any alteration in design, without the addition of any article or parts, and without the removal of any article or parts that are not to be replaced." Repairs are classified according to the agency that makes them. They fall into three classes: ship's force, tender, and Navy yard.

Repairs performed by the ship's force are limited by the lack of facilities and tools on board. For that reason, such repairs are usually confined to replacing worn parts and making minor adjustments. It's the torpedo officer's duty to see that complete sets of spare parts for these repairs are kept on hand. He must also establish a follow-up system to ensure replacement of all parts used.

Ships are periodically assigned to Navy yard overhaul, for repairs beyond the capabilities of the ship's force. During these periods, all repairs that cannot be accomplished by the ship's force or the tender are undertaken. Such repairs might include lifting and aligning the tube mounts, lifting the director or data computer, rewiring torpedo control circuits, and similar extensive jobs. The torpedo officer is responsible for making the necessary requests for both tender and Navy yard repairs, and for seeing that the job is done properly, no matter what agency does it. Repairs not checked may result in failure after the ship has left the tender or Navy yard.

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ALTERATIONS include all additions to any articles or parts, and the removal of any articles or parts that are not to be replaced by similar ones. No alterations may be made to any vessel, or to any articles aboard, without the specific approval of the bureau concerned. Alterations to torpedoes and their related equipment are authorized by BuOrd OrdAlts. The torpedo officer is responsible for seeing that all alterations authorized by OrdAlts are made as promptly as possible. If he feels that some alterations not authorized by OrdAlt is necessary, he may send a request, through channels, to BuOrd. His information on this point will probably come from you. You should be able to explain why the requested alteration is necessary, and what services and materials will be required to make it. This information will help the gunnery officer in originating the request, and will assist the commanding officer, who must sign such requests and submit them to higher authority.

SAFETY

You already know that you are responsible for observing all the necessary safety precautions. And the higher you go in your rating, the greater your responsibility will be.

You are responsible first of all for your own personal safety, and second for the safety of the men under your supervision. These two are closely tied together. Your men will watch what you do, and they will imitate you. Setting them a good example in safe practice is just as important as careful training and supervision.

Finally, you are responsible for the safety of the Navy equipment you work with. That includes a broad range of responsibilities. It includes such simple things as training your men to use an ammeter properly, so they won't burn out its coil by trying to use it as a voltmeter. At the other extreme, you must train your men in safe handling of torpedo war heads and submerged torpedo

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tubes, where carelessness might endanger the whole ship and the life of every man aboard.

We suggest that you make a careful review, first, of safety regulations in general. You'll find them in the *Bureau of Ordnance Safety Precautions* manual. Next, study the safety precautions that apply to your particular job. Nearly every Ordnance Pamphlet includes a list of special safety precautions to observe in handling the particular equipment it describes.

Study your job, and your working space, for special hazards. You'll be working with high explosives in the torpedo war head, and with high-pressure air in the air flasks and charging lines. If you work with electric torpedoes you'll handle strong acid (for the electrolyte), and you'll work with moderately high voltage in the battery and its charging circuit.

So learn safe practice for yourself, then carefully train your men in safe practice. And finally, ENFORCE safe practice. You aren't doing your men a favor when you tolerate carelessness.

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QUIZ

1. Why should you review the things you've already learned about torpedoes?
2. What subjects does Volume 2 of this course deal with?
3. On a destroyer with trainable tubes, who usually parallels electric firing with percussion firing?
4. Where can you find information on depth charges and launchers?
5. On a submarine, who usually operates the blow and vent manifold and the tube poppet valves?
6. Why is it necessary for you to know the duties of the torpedo officer?
7. List briefly the principal duties of the torpedo repair officer on a repair ship.
8. Under what conditions may you alter the design of torpedoes or torpedo equipment?

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CHAPTER 2

PAPER WORK

If you think paper work is boring, you're in the majority. There's nothing exciting about it, and we don't know anybody who really likes it.

But it takes more than ships and men and weapons to run a Navy. It also takes tons and tons of paper. Without its records, reports, and requisitions, the Navy would be paralyzed. Prompt and accurate paper work is so important that very little of it is entrusted to the lower rates. That's why your responsibilities in this field will increase as you advance in rating.

It doesn't take much thought to see why paper work is essential. The Navy must maintain the highest possible fighting efficiency with the money it has available. It can do this only if all supplies and equipment are carefully controlled and accounted for. Your ship must maintain adequate stocks of supplies, spare parts, and equipment. These items must be replaced from time to time as they are drawn from stock. All this requires accurate, up-to-date records.

The Bureau of Ordnance is responsible for the design, manufacture, procurement, issue, maintenance, and efficiency of all offensive and defensive arms and armament. To control the manufacture, procurement, and issue of weapons and spare parts, BuOrd must know the location and condition of all the weapons in the Fleet. It must have accurate data on the performance and maintenance

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history of all these weapons, in order to know when a new design or a new maintenance procedure is necessary. BuOrd can't function without a constant flow of information from the fleet. It gets this information largely from the regular reports submitted by the gunnery compartment. The gunnery officer will base his reports largely on information in the records you will keep.

In summary, here are the main reasons why records and reports are necessary.

1. To keep an accurate account of all material issued and expended.

2. To keep an accurate account of all material on hand, in store, and in reserve.

3. To insure compliance with war plans.

4. To provide data required by the Department of the Navy and its bureaus.

5. To keep an accurate record of ammunition performance.

6. To enable the Bureau of Ordnance to withdraw faulty, unserviceable, or otherwise unsatisfactory ammunition from the fleet.

YOUR JOB

In general, the paper work you are likely to do can be divided into three kinds. You will probably—

1. Make reports (including performance reports, inventory control reports, and special reports).

2. Keep records (including performance and maintenance records for underwater ordnance and equipment).

3. Make requisitions and write letters of request.

You will probably be expected to know about the reports prepared by the gunnery department—at least those that deal with underwater ordnance. The reports required, and the forms you use for them, are changed

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from time to time as conditions change. That's why we can't give you a list of forms and expect it to stay up to date. The best we can do is mention some of the more important reports now in use. Instructions from the Bureau of Ordnance furnish the latest information.

You will be expected to prepare standard work requests and job orders. The exact form of these orders varies, depending on where you are stationed. You may have to supervise the accounting of stores and spare parts, and to order replacements. These jobs call for a knowledge of ordnance inventory control forms, an ability to make out a requisition or write a letter of request, and a general knowledge of how the Navy supply system operates.

You will probably have to supervise the maintenance of records for underwater ordnance and equipment. The forms used for these records are subject to change. We will discuss some of the more important records and forms now in use. Your torpedo officer or gunnery officer can give you the latest information.

NAVY SUPPLY

Before we go into detail about your specific jobs, we'll give you a short outline of the Navy Supply system as it applies to ordnance supplies. We'll deal more with supply afloat than supply ashore, since most of your supply activities will probably be afloat. If you find that you need more detailed information than we can give you here, refer to the *Bureau of Supplies and Accounts Manual.*

In this chapter we will tell you: (1) who is responsible for supply, (2) how to identify the thing you need, (3) how to get it, (4) how to account for it after you get it, (5) how to get it out of store when you need to use it, (6) what records you keep concerning it, and (7) who takes care of it, and how.

The Navy-wide supply system varies in detail from one

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bureau to another. But in every bureau the supply system has these two aims: to get materials from their sources (PRODUCER LOGISTICS), and to deliver these materials to the user (CONSUMER LOGISTICS).

CONSUMER LOGISTICS. The Chief of Naval Operations and his fleet commanders are responsible for the broad phases of consumer logistics. They estimate what supplies will be needed, plan where they will be used, and decide how to distribute them. Service force commanders are responsible for those details of the supply program that are related to their work. The responsibility for supply moves on down the line to the commanding officer and supply officer on your own ship. Figure 2–1 shows how the supply department might be set up on a typical small vessel.

PRODUCER LOGISTICS. The Secretary of the Navy and the various material bureaus are responsible for producer logistics, including the CONTROL of supply. The Bureau of Supplies and Accounts (BuSandA) makes the general rules for cataloging, inventory control, procurement, accounting, issuing, and disposal. But each technical bureau is responsible for the design, manufacture, technical supervision, inspection, and upkeep of its own specialized equipment.

SUPPLY OFFICES. Each technical bureau (including BuOrd, of course) has an agency or group of agencies to coordinate the technical functions of the bureau with the supply functions of BuSandA. These agencies are called supply-demand control points, or SUPPLY OFFICES. Each naval supply office has Navy-wide control over an assigned group of stock classes. A supply office is responsible to its parent bureau for technical accuracy, and to BuSandA for business management. The Ordnance Stock Office (OSO), which we'll discuss later, is a supply-demand control point for BuOrd.

SUPPLY CENTERS. The supply offices seldom have materials sent directly from manufacturer to consumer;

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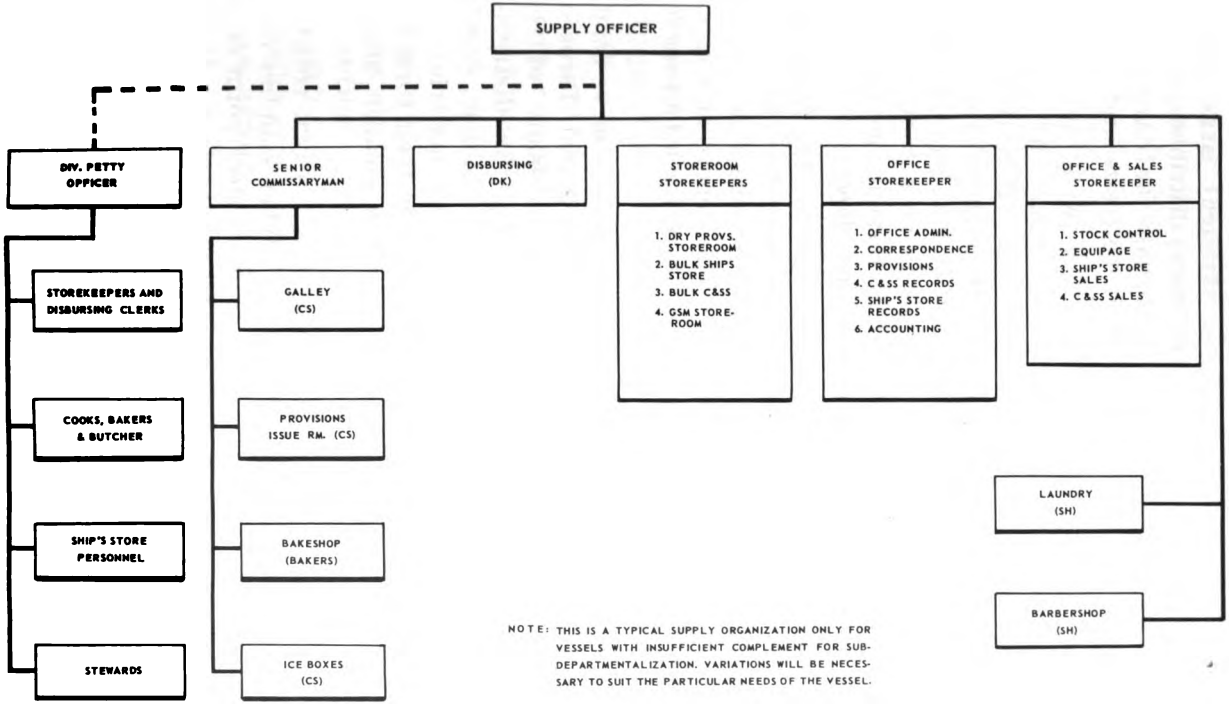

Figure 2–1.—Supply department of a typical small vessel.

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they usually send them to (or through) large supply centers, or DEPOTS. The depots stock, distribute, and/or control specialized types of materials for naval units assigned to them. Depots vary in both size and duties.

DISTRIBUTION SYSTEM. The Navy-wide system of stock distribution is easier to understand if you remember its main purpose: to keep materials flowing smoothly from the manufacturer, through storage, to the user. As far down the line as they can, supply offices control the flow of new materials in an automatic and routine way. This saves a lot of correspondence between lower and higher echelons of storage depots.

A supply office usually has new goods sent from the manufacturer to a RESERVE STOCK POINT. The name explains itself: a reserve stock point carries reserve and back-up stocks for the system. The depots at Crane, Ind., and Yorktown, Va., are examples of BuOrd's reserve stock points.

Replacement stock usually moves from a reserve point to a DISTRIBUTION POINT—such as the Naval Torpedo Station at Newport. Your ship sends many of its requisitions directly to distribution points. But distribution points have other duties besides filling direct requests. They also forward replacement materials to PRIMARY STOCK POINTS. The primaries, in their turn, fill requisitions sent in by ships and the smaller shore activities.

Some shore activities, called SECONDARY STOCK POINTS, carry only a limited range of stock. When supplies run low, they send a requisition to a primary stock point or a distribution point, whichever is more convenient. Your ship probably gets some of its equipage from secondaries.

That, in brief, is the Navy-wide stock-distribution system. All the terms really explain themselves. All the units of the system share one purpose: to get stock from the manufacturer to the consumer with as little letter-writing and as little lost motion as possible.

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BuOrd Supply Systems

The paragraphs above deal with the Navy Supply system in its broadest terms. Each bureau adapts this system to its own specialized materials. In doing this, a bureau is allowed to break the general system down into several smaller systems, as long as each system follows the master pattern.

The Bureau of Ordnance has six of these smaller systems—one for each of the following classes of material:

1. Material under OSO control.
2. Major equipment under direct BuOrd control.
3. Gun ammunition.
4. Aviation ordnance.
5. General stores.
6. BuOrd electronics material.

Four of these classes (1, 2, 4, and 6) are of interest to Torpedoman's Mates.

ORDNANCE STOCK OFFICE. We have mentioned OSO as a BuOrd supply office. OSO was set up in the Bureau proper in 1942. During the next year it was moved to the Naval Gun Factory. There it was given more and more responsibility for inventory and stock control. When the present Navy supply system was adopted in 1946, OSO was ready to do all the work of a supply-demand control point. It has continued to grow since that time.

OSO is divided into three groups. A SUPPLY GROUP studies supply-demand reports and sends materials where these reports show they are needed. A MACHINE SERVICE GROUP uses an elaborate machine-bookkeeping system to collect and partly analyze supply-demand reports for the supply group. A TECHNICAL GROUP takes charge of stock identification, numbering, and cataloging, and prepares the BuOrd section of the *Catalog of Navy Material.* This catalog sets up standard symbols that you will use in describing and ordering hundreds of ordnance items.

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OSO has supply-demand control over tools, accessories, subassemblies, and repair parts for many ordnance items, including some underwater ordnance. It also has charge of certain fire control equipment, vessel sets, and tender sets.

BUORD. BuOrd itself serves as the supply office for some of the major equipment used by the Navy. Examples are degaussing apparatus, advanced-base materials, and various items with a high security classification.

AVIATION ORDNANCE SUPPLY. The Aviation Ordnance section of the Material Division of BuOrd is the supply-demand control point for some of the equipment you may use if you ever help an Aviation Ordnanceman with his work. Examples are aircraft pyrotechnics and various munitions-handling devices.

ORDNANCE ELECTRONICS SUPPLY. The supply of some of the electronics equipment you will use is under direct BuOrd control. (Other electronics material is under BuShips, and is controlled by that bureau's Electronics Supply Office.)

We have kept this discussion as short as possible. But it should at least remind you that any technical specialist, such as a TM1 or C, gets his gear from several sources. BuOrd issues instructions from time to time on how and where to order certain items. Your supply officer keeps these instructions on file. We suggest that you borrow them and study them.

CLASSIFICATION AND IDENTIFICATION

Like any other specialized activity, Ordnance supply has a set of words and symbols that it uses with special meanings. If this were not true, the thousands of people who order, tabulate, move, store, and repair ordnance gear throughout the Navy would never be sure they were talking or writing about the same item. Let's look at some of the words you will have to use in requesting underwater ordnance.

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SUPPLIES. This term refers to stores that are consumed when they are used. (It does not include spare parts for nonconsumable equipment.)

EQUIPAGE. This term is applied to stores that are not consumed. They are usually of greater value than consumable supplies, and are of permanent functional importance. Responsibility and accountability for equipage continues after it is issued, and until it is disposed of. Ordnance equipage consists of all the ordnance material so designated by the Bureau of Ordnance. (A list of underwater ordnance equipage appears later.)

Equipage has these characteristics—

1. The material must be accounted for after it has been put to use, and until it is finally disposed of.
2. It is not installed as a permanent fitting, but is usually portable or semiportable.
3. It is usually expensive.
4. It depreciates slowly.
5. Because it is expensive and portable, it needs special protection against theft.

Equipage used to be identified, for accounting purposes, as "Title B" material. It is now identified by a five-digit number, as follows:

Ships equipage—a figure in the 12000 series.

Ordnance equipage—a figure in the 22000 series.

Aviation equipage—a figure in the 32000 series.

Below is a list of underwater ordnance material and equipment that the Bureau of Ordnance has classified as ordnance equipage. (Custody signatures are not required for installed equipment or parts marked by an asterisk in this list.)

Torpedo and torpedo components, as follows:

Torpedo.

Torpedo depth and roll recorder.

Torpedo exercise head.

Torpedo exploder mechanism.

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Torpedo gyro.
Torpedo locating device.

Torpedo workshop equipment, tools, and accessories, as follows:

Afterbody adjusting stand.
Bench lathe.
Control-valve test panel.
Crosby fluid pressure scale.
Depth mechanism test stand.
Engine overhaul stand.
Governor test stand.
Gyro adjusting stand.
Gyro reducing-valve test panel.
Gyro running-balance test stand.
Gyro wheel-centering fixture.
Lapping and polishing machine.
Leak meter.
Leakage test stand.
Oil pump test stand.
Reducing-valve test outfit.
Reducing-valve test panel (for torpedo Mk 16).
Spray and check valve test outfit.
Torpedo test panel (general use).
Torpedo truck.

Torpedo tubes, launching racks, and components, as follows:

Torpedo launching rack.
Torpedo tube.
*Torpedo-tube mount.
Torpedo-tube sight (mechanical).
Mine and depth charge equipment, as follows:
*Depth-charge release track.
*Depth-charge release track control.
*Depth-charge release track extension.
Depth-charge release gear.
Depth-charge test set.

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Mine locating device.
Mine test set.
Ordnance detector.

MATERIAL AND STORES. These are general terms; they apply to both consumable supplies and equipage.

ORDNANCE SPARE PARTS. This term refers to items used in maintaining ordnance equipment. These items include integral replacement parts, and any special tools required for a particular piece of ordnance equipment. Included are spare parts for torpedoes and depth charges, and for all launching and storing equipment for torpedoes and depth charges.

ALLOWANCE LISTS. These provide a complete list of equipage and consumable supplies to be placed aboard vessels. Each list includes all the equipment needed for efficient operation and maintenance of one type of ship. Vessels are required to carry a full allowance of equipage and spare parts, but they are not permitted to exceed that allowance without special approval by BuOrd.

For consumable supplies, the allowance lists show the kinds and amounts of materials needed to operate the ship. You will probably use the allowance lists to prepare custody and stock records; to prepare requisitions for replacement material; as a basis for coding material (by stating the group, page, and line number); and to show the proper identification of technical spare parts aboard.

Ordnance allowance lists are prepared by the Ordnance Stock Office and by the Naval Torpedo Station, Newport, under the direction of the Bureau of Ordnance. A separate list is prepared for each type of ordnance equipment furnished to vessels by the bureau. Two copies of the lists are furnished to vessels for each type of equipment carried aboard. Usually, the department head and the supply officer will each keep one copy of the lists.

The ordnance allowance list for each type of equipment includes—

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1. A description of the basic equipment, including piece and drawing numbers.

2. Lists of spare parts, tools, accessories, and supplies that make up one full set of spares for the equipment.

3. A key that shows how many full sets of material are required, depending on how many units of the equipment are installed aboard.

Each allowance page bears a sheet number and page number, and the items on each page are designated by item numbers. For each unit of equipment, the first page of the list shows the sheet numbers that make up the complete list.

WARNING. Allowance lists are often changed. If you have the job of entering revisions, do this as soon as they come to you. Don't put it off. When you need a replacement, you'll need it right away. You won't have time to go back over a pile of revision sheets looking for the information you need.

Classification Symbols

Classification symbols are a kind of shorthand. They enable you to get the exact item you need, without writing a long description of it. It's obvious that you can't get the item you want unless you use the correct name and symbols. Being almost right is no help here; you have to be absolutely right.

As we told you, the technical group at OSO assigns the stock numbers to standard BuOrd equipment. This work is done under the general rules outlined in the *BuSandA Manual,* paragraph 2205–1. This paragraph adapts the general federal stock-classification system to Navy use.

The Navy material classification system divides naval stores and material into 99 numbered classes. Each class represents one type of material. Most ordnance material falls in one of these classes: 1 through 4, 74, 94 through 97, and 99. When ordnance material is

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identified by standard stock numbers, these numbers are preceded by the letter "Z" (showing OSO control), or by the letter "J" (showing BuOrd control). After the stock class number comes more detailed information, such as a drawing number, sketch-list number, or manufacturer's number.

Some ordnance material is non-standard, and doesn't fit in the above classification. When you refer to this kind of material, you'll need some or all of these numbers:

1. The Mark and Mod numbers.
2. The drawing number on the BuOrd blueprint.
3. The assembly or piece number shown on the blueprint.
4. The serial number (if any) stamped on the equipment.

You will sometimes have to refer either to an OP or to a manufacturer's instruction book to find the symbol for the part you want to order. The engineering officer and the gunnery officer keep these pamphlets on file. Here's something to remember: when you find the exact symbol you need, be sure to copy it accurately and completely. If you don't your requisition will come back to you for correction, and you'll lose a lot of time.

Catalog of Navy Material

The *Catalog of Navy Material* is a valuable reference book for ordnance specialists. It is divided into small units, each one covering only a limited class of stock. This makes it easy to send each unit to the men most likely to need it. To help you keep your part of the book in order, the pages are marked with both page and unit numbers at the lower right.

The BuOrd section of the catalog is for the use of everyone who deals with Naval ordnance, whether in the office, aboard ship, or at a shore activity. For each item listed, it tells what it is, where it fits, whether it is carried as a spare, and, if not, how to order it.

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In the ordnance section of the catalog, all material is divided into two classes: WHAT IT IS, and WHERE IT FITS.

The WHAT IT IS class includes items for general use, such as gaskets, bolts, and rivets. Each item is described in detail, to help you find and order the right one.

The WHERE IT FITS class includes complicated ordnance items like torpedoes. Such material is arranged by the "top-down" method. That is, similar equipments are treated in such a way as to show the following breakdown of information:

1. The major components of each equipment;
2. The subassemblies and parts of each major equipment;
3. The parts that make up each subassembly.

The WHERE IT FITS units of the catalog explain BuOrd's rules for maintaining, stocking, and ordering each assembly. You may find, for example, that a given assembly is not supplied as a unit, but that you can build it up from parts that ARE supplied. On the other hand you may find that the part you need is not supplied as such, but that you can get it by ordering the assembly that includes it.

The WHERE IT FITS listings often follow this pattern:

1. General characteristics and information tables.
2. Major breakdown and index sheet.
3. Tables of assemblies and parts.
   a. Assembly indexes.
   b. Component breakdown tables.
   c. Table of parts.
4. Numerical parts list.
5. Cross-reference tables.
6. Special tools list.

At the beginning of each WHERE IT FITS unit, you will find a few sentences that tell what the unit contains, and how you can use the tables. Many of the tables are provided with additional instructions. Some of these, when

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you first read them, may seem hard to follow. If so, we suggest that you try this: choose some subassembly that you're already familiar with. Pretend that you know only half the necessary facts about it. Using that half as a start, work your way through the tables to find the other half. After a few self-umpired exercises like this one, you'll find the tables much easier to use.

The drawings in the catalog will help you to identify parts. Each drawing is placed as near as possible to its table or tables. The numbers on these drawings key them to the tables for cross-reference purposes.

ORDERING ORDNANCE MATERIAL

There are two ways to order Navy material—by LETTER OF REQUEST, and by REQUISITION.

Letters of Request

The letter of request is the formal way to order. It must be used for many ordnance items, including torpedoes and some torpedo equipment, detonators, and all explosives. The letter is sent from your commanding officer to the Chief of the Bureau of Ordnance, or to some one properly authorized to act for him. Your CO depends on his department heads for the correct technical information. And your department head will expect you, as a TM First or Chief, to be his technical expert.

Letters of request follow a set form. Your torpedo officer may have you draft each letter in full, or he may simply ask you to furnish the technical information that he will use in the letter. We have already mentioned the need for care in copying this information. Taking time to double-check your identification symbols is good economy in the long run.

Requisitions

You will use requisitions to order both equipage and supplies. Items of equipage are indentified by name and symbol on the ship's allowance lists. The material you want to order is either IN-EXCESS or NOT-IN-EXCESS.

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NOT-IN-EXCESS. Each time an item on the ship's allowance list is expended, a not-in-excess requisition is used to order a replacement. If the supply officer has custody of the item, he makes out the requisition himself. But some items are in the custody of your department head. When such an item is issued for use, the department head gives a filled-in STUB REQUISITION (NavSandA Form 307) to the supply officer, who then orders a replacement.

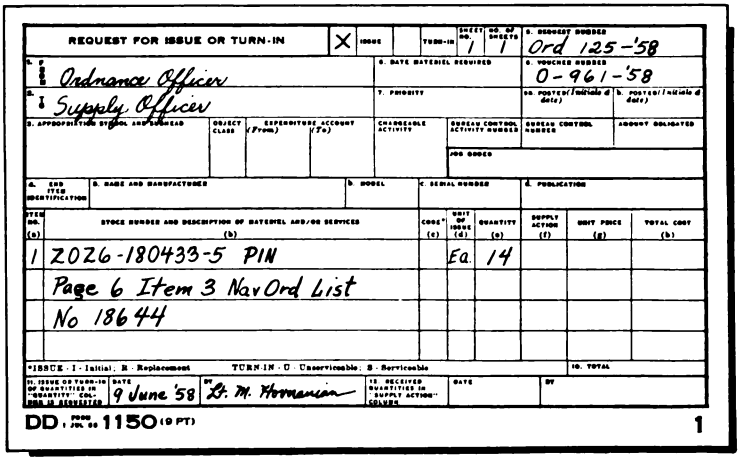
The following classes of material are not-in-excess items:

1. Equipage to fill the ship's allowance;

2. Consumable supplies listed in the *Catalog of Navy Material* or included in the ship's allowance; also unlisted but fully acceptable substitutes for these supplies;

3. Material needed for immediate repairs or alterations to equipage, or for replacement of material already expended in such repairs or alterations.

For some classes or material, you must have not only a stub requisition but also a REQUEST FOR ISSUE OR TURN-IN, DD Form 1150, shown in figure 2–2. Your department



REQUEST FOR ISSUE OR TURN-IN | X | ISSUE | | TURN-IN | SHEET NO. 1 | NO. OF SHEETS 1 | 5. REQUEST NUMBER Ord 125-'58

a. FROM: Ordnance Officer | 8. DATE MATERIEL REQUIRED | 6. VOUCHER NUMBER 0-961-'58

b. TO: Supply Officer | 7. PRIORITY | 6a. POSTED (Initials & date) | b. POSTED (Initials & date)

3. APPROPRIATION SYMBOL AND SUBHEAD | OBJECT CLASS | EXPENDITURE ACCOUNT (From) | (To) | CHARGEABLE ACTIVITY | BUREAU CONTROL ACTIVITY NUMBER | BUREAU CONTROL NUMBER | AMOUNT OBLIGATED | JOB CODES

4. END ITEM IDENTIFICATION | 5. NAME AND MANUFACTURER | b. MODEL | c. SERIAL NUMBER | d. PUBLICATION

ITEM NO. (a)	STOCK NUMBER AND DESCRIPTION OF MATERIEL AND/OR SERVICES (b)	CODE* (c)	UNIT OF ISSUE (d)	QUANTITY (e)	SUPPLY ACTION (f)	UNIT PRICE (g)	TOTAL COST (h)
1	2026-180433-5 PIN		Ea.	14			
	Page 6 Item 3 NavOrd List						
	No 18644						

*ISSUE - I - Initial, R - Replacement TURN-IN - U - Uneconomical; S - Serviceable 10. TOTAL

11. ISSUE OR TURN-IN OF QUANTITIES IN "QUANTITY" COLUMN IS REQUESTED | DATE 9 June '58 | BY Lt. M. Hermanson | 12. RECEIVED QUANTITIES IN "SUPPLY ACTION" COLUMN | DATE | BY

DD FORM 1 JAN 48 1150 (9 PT) 1

Figure 2–2.—Request for issue or turn-in.

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head signs this form, but you will probably fill it in for him.

IN-EXCESS. No one likes in-excess requisitions, but sometimes they are unavoidable. Requisitions for the following classes of material are regarded as in-excess:

1. Equipage not on the ship's allowance lists;
2. Equipage on the allowance lists, but requested in larger quantities than the lists specify;
3. Consumable supplies not on the ship's allowance lists, and not standard stock, which will NOT be used for the purpose mentioned on allowance lists or in the Catalog of Navy Material.

In-excess requisitions must be sent by your CO to the type commander. The type commander will review them, and then forward them to the bureau that has charge of the equipage. Except in grave emergencies, that bureau must approve the request before any in-excess material can be shipped to you. So never present a request for in-excess material unless you have facts to back it up.

If the supply of certain items keeps running short, in spite of reasonable care, your CO may request changes in the ship's listed allowance. These changes must be reviewed by the type commander. If he gives his approval, he extends it to cover all ships of the same class as yours.

GENERAL INSTRUCTIONS FOR PREPARING REQUISITIONS. Your ship has guides for you to use in preparing requisitions. Some of them are the *Catalog of Navy Material,* the allowance lists, and certain stock cards issued by OSO.

The items on a requisition must be listed in the same order as on the allowance list. Give complete details; there must be no question as to exactly what you are ordering.

When you have to use the request for spare parts, NavSandA Form 302, complete it in full. Otherwise, it will come back to you stamped "DISAPPROVED; ADDITIONAL INFORMATION NECESSARY."

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Never put in-excess and not-in-excess items on the same requisition. Remember that the two classes receive entirely different handling.

If you have BuOrd authority for your requisition, mention this authority. If there is no covering authority, explain clearly why the service or material is necessary. Otherwise the request will not be approved.

If you are required to state the number of spares on hand, count only the ACTUAL SPARES, not the total number on board.

If the articles on a requisition are to replace surveyed material, state this fact clearly, and specify the survey report. Such articles are not-in-excess replacements.

Forwarding Requisitions

Not-in-excess requisitions, and approved in-excess requisitions, will normally be sent to the nearest primary source of supply. For ordnance spare parts, tools, and accessories, these are the primary sources of supply for all vessels:

1. Infantry equipment; and spare parts, tools, and accessories for small arms—

Ordnance Supply Depot, Naval Supply Center, Norfolk.
Ordnance Supply Depot, Naval Supply Center, Oakland.
Ordnance Supply Depot, Naval Supply Center, Pearl Harbor.

2. Spare parts, tools, and accessories for torpedoes and torpedo workshop equipment—

Naval Torpedo Station, Newport.
Naval Torpedo Station, Keyport.
Ordnance Supply Depot, Naval Supply Center, Pearl Harbor.

3. All other ordnance spare parts, tools, and accessories—

Naval Supply Depot, Bayonne.
Naval Shipyard, Mare Island.
Ordnance Supply Depot, Naval Supply Center, Pearl Harbor.

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Under certain conditions, you may submit requisitions to secondary or other sources of supply. Current orders will tell you what to do.

Receipt of Material

The supply officer, if you have one aboard, is responsible for the receipt of all ordnance material except installed ordnance equipment and expendable ammunition. He receives portable items of ordnance equipment, and all ordnance spare parts.

The commanding officer will decide whether a given class of material will be under the custody of the supply office or of a department head. If the material is to be held in the custody of the supply officer, the storekeeper in charge takes the material into the storeroom. He may ask a representative of the gunnery department (who is familiar with the material) to inspect the parts, to help identify them and to determine whether or not they meet specifications. This inspection is the responsibility of the supply officer. But if the material is turned over to the custody of the gunnery officer, then HE assumes responsibility for the inspection.

If the material is to be held in custody by the head of the gunnery department, the parts will be turned over to a representative of that department, who will acknowledge receipt by signing the invoice.

Issues of Ordnance Spare Parts

The term ISSUES refers to the release of material for use. When the supply officer has custody, and the gunnery department needs a spare part, the gunnery officer will prepare a Stub Requisition (BuSandA Form 307) in duplicate, and sign both copies. Here are the rules for preparing a stub requisition:

1. Show the name of the equipment for which the part is needed.

2. Give the complete nomenclature of the part.

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3. Show the number and/or location of the mount for which the part is required.

4. Include parts for only one type of equipment on a single stub.

When the stub requisition has been properly filled out, it will be presented to the storekeeper in charge of ordnance spare parts. The storekeeper will check to see that the stub contains all the information needed to identify the part, so that he can prepare a replacement requisition. He will then issue the part, and obtain the signature of the person who receives it.

The storekeeper will indicate on the face of the stub requisition the number of the spare parts box from which he took the part, so that he can put this information on the replacement requisition. A serial number should be assigned to the stub (using a separate series for ordnance spares), the issue noted in a book, and a copy of the stub filed as the supply officer may direct. This copy of the stub will remain in the spare parts box, or otherwise in the custody of the storekeeper until it is replaced by a copy of the replacement requisition.

The original of the stub requisition is forwarded to the supply office, to be used in the preparation of a replacement requisition.

When the gunnery officer has custody of spare parts boxes, it is his responsibility to establish an issue system. This system must provide for prompt notification of the supply officer after each withdrawal from the spare parts boxes. The gunnery officer will request replacement of the material on a stub requisition. The original of this stub requisition will be sent to the supply officer, who will prepare a requisition for replacement of the parts used.

Transfers of ordnance and ordnance spare parts will be made only by the supply officer, on regular transfer invoices. After the transfer is made, expenditure will be made from the spare parts stock card (if one is maintained), and a replacement requisition prepared in the usual way.

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INVENTORY CONTROL

The supply officer has over-all responsibility for stock records and inventory control for all the equipage aboard his ship. He keeps the custody records on NavSandA Form 306. Each time he releases an item to the custody of a department head, the department head must sign this form.

Your department head, in turn, has a duplicate set of forms to keep track of all the equipage charged to his custody. When he assigns custody of equipage to you, he'll ask for your signature on NavSandA Form 306, and give you a carbon copy for your records. This makes you personally responsible for the equipage. Don't turn it over to anybody else unless you get a receipt for it. Keep the receipt on file until the material is returned to you.

Once each year, and at other times as required by *Navy Regulations*, your department head will make a complete inventory of the equipage in his department. You will probably help him with this job.

Surveys

A survey is a means of bringing the equipage records up to date. *Navy Regulations* require a survey whenever any item of equipage is lost, missing, worn out, or broken beyond economical repair. There are two classes of surveys—informal and formal.

INFORMAL surveys are made by the department head who has custody of the material.

FORMAL surveys are made by a one-man or three-man board appointed by the CO. He is not allowed to appoint any of the following to a formal survey board:

Himself;

The officer on whose books the articles are carried;

The officer having custody of the articles.

It is not necessary to send a report of the survey to the Bureau of Ordnance unless bureau approval is specifically required by higher authority. When Bureau authority

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is required a copy of the report must be forwarded promptly, so that the Bureau can direct any changes it may want to make in the disposal action.

Whether or not a copy is sent to BuOrd, the survey must be recorded on NavSandA Form 154 (fig. 2–3). For torpedo equipage Form 154 will be signed by the tor-

NAV. S. AND A. FORM 154 (Rev 4-49)

SURVEY REQUEST, REPORT, AND EXPENDITURE

SHIP OR ACTIVITY: U. S. Naval Mine Depot Yorktown, Va. | DATE: 8/6/– | NO.: 342561

REQUEST (To be prepared by supply officer, or head of Department)

It is requested that the items listed below be surveyed in accordance with Sec. 3, Chap. 19, N. R.

REASON: Unfit For Issue | APPROPRIATION: 17x4991 | SIGNATURE: W.R. Jones W.R. Jones

ASSIGNMENT | NAME: Capt. SC USN

ITEM	QUANTITY	ARTICLE	SHIPPING MARKS, ETC.	DATE AND FROM WHOM RECEIVED	VALUES AT WHICH CHARGED
1	100 Cans	Cement, Liquid Rubber Type, 1 Pint Can	G52-C-1566-755	NSD Norfolk	$ 73.00

REPORT (To be prepared by head of Department, or by surveying officer(s) if so directed below)

ITEM	CONDITION, CAUSE, RESPONSIBILITY, AND RECOMMENDATION	APPRAISED VALUE
1	Condition: Dried Out And Hardened. Cause: Age Through Extended Storage. Packed In 19— Responsibility: None. Recommendation: Sent To Storage Yard For Dumping. Expended From Records.	

The above items have been carefully surveyed in accordance with Sec. 3, Chap. 19, N. R., and report is made thereon as indicated above.

DATE 8/12/–

(Signed by surveying officer or board, or by head of Department)

ACTION OF COMMANDANT OR COMMANDING OFFICER

Expend without formal survey, in accordance with Sec. 3, Chap. 19, N. R. | DATE | COMMANDANT OR COMMANDING OFFICER

or Formal survey is required and

John J. Brown, LCDR. U. S. N. George H. Gdanic, LCDR. U. S. N.

Albert L. Doe, LTJG U. S. N. (are) hereby designated as surveying officer(s) for the above articles or material, in accordance with Art. 1947, N. R.

8/10/– (Date) A.B. Brown A.B. Brown Capt. USN (Commandant or Commanding officer)

ACTION BY REVIEWING OFFICER AFTER SURVEY

ITEMS APPROVED	ITEMS DISAPPROVED	DATE	SIGNATURE
1		8/13/	A.B. Brown, Capt. USN

NAME OF BUREAU TO WHICH FORWARDED FOR ACTION (If required) | DATE

The above articles have been expended from the records at

FINAL EXPENDITURE

	APPROPRIATION	CHARGE TO EXPENDITURE ACCOUNT
$ 73.00	USF 17x4991	99001

TRANSFERRED TO

SPACE FOR BUREAU APPROVAL IF NECESSARY

EXPENDED/DISPOSED 15 Nov 19— the above-mentioned articles W. R. Jones W. R. Jones, Capt. U. S. N.

U. S. GOVERNMENT PRINTING OFFICE 16—20020-6

Figure 2–3.—Survey form (NavSandA Form 154).

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pedo officer, but you will probably fill in the necessary information for him.

When you dispose of surveyed material, set aside all parts and subassemblies that are in good enough condition to be of use to your ship, or to tenders, repair ships, or shipyards. These items will either be used locally, or turned over to another activity for salvage.

If you need more information on surveys, you can find it in chapter 19 of U. S. *Navy Regulations,* and in the BuSandA publications *Supply Ashore* and *Supply Afloat.*

RECORDS AND REPORTS

The *Bureau of Ordnance Manual* calls for a variety of ordnance reports to be submitted at intervals by all officers in command ashore; by commanding officers of naval air stations and marine air stations; by commanding officers of Naval ordnance stations, plants, and depots; and by the commanding officers of all ships.

The number and type of reports required are changed from time to time as conditions change. For that reason, we won't try to give you a complete list of them.

Here's how to find out what reports are currently required. Your ship or station maintains a file of NavOrd Instructions. Look up the latest instruction numbered 5215.11. This will give you an alphabetical list of NavOrd Instructions, by subject. In this list, find the heading REPORTS; note the numbers of all instructions under that heading that deal with torpedoes or related equipment. Check these numbers against the numerical listing in the latest issue of NavOrd Instruction 5215.10. This will tell you which of the instructions on your list are still in effect. Then look up the individual instructions in the file. They will tell you what reports are required, how to fill them out, and where and when to forward them.

In this chapter, we will discuss only a few of the most important records and reports likely to be required by the

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Bureau of Ordnance, or by your gunnery officer. These include the torpedo log, the torpedo record book, the report of unsatisfactory or defective torpedoes or equipment, and the work request. Some of this work—especially the torpedo record book—will probably be handled by the lower rates. But supervising their work will be a part of your job.

The Torpedo Log

The torpedo log is an hour-by-hour and day-by-day account of the activities of the torpedo crew and its ordnance. It is important for several reasons:

1. It helps members of the torpedo crew, and their successors, in the maintenance and operation of the torpedo battery.

2. It gives you the information you will need to prepare other records and reports.

3. It enables you to anticipate the necessity for equipment overhaul before casualties occur.

4. It helps you to prevent the recurrence of casualties, and,

5. It shows when improvements in methods or equipment are advisable.

There is no set form for the torpedo log. It will differ on different ships. Some commanding officers will want more detailed entries in the log than others. In general, your entries will include information on—

1. Upkeep routines on torpedoes or tubes: Defects noted; repairs made; parts of routine that could not be carried out.

2. Preparation for firing: Dates of preliminary and final adjustments; difficulties in making adjustments.

3. Firing: Tube number from which each torpedo is fired; results of run; disposition of torpedo after exercise run.

4. Overhauls of tube mechanism: Drawing number of parts renewed.

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5. Receipt of torpedoes from tender, or transfer of torpedoes to tender for overhaul.

6. Igniters drawn, and disposition of fired igniters.

7. Defects noted on inspections.

8. Receipt, transfer, loss of, or damage to, any equipment.

9. Inventories of equipment and spare parts.

It's a good idea to use one or more pages of the log for a record, in table form, of all the torpedoes aboard. This table should show the location of each torpedo; when it was last overhauled; when it was last fired for test or practice; the result of the last run; and any other information you think necessary. Similar tables for gyros, war heads, and other gear might be useful.

The log frequently includes a work list, showing repairs or changes that should be made by the ship's force, the tender, or the Navy yard. You can set down these recommendations for this work whenever your maintenance routine, operation, or inspection shows them to be advisable. When the work is completed, you can check it off on the work list.

Torpedo Record Book and Forms

A torpedo record book goes with each torpedo from "cradle to the grave". Its official designation is NavOrd Form 52, Manufacture-Service Record of U. S. Torpedo. It's a life history of the torpedo. It contains a record of its manufacture, tests, proof, overhaul, repairs, alterations, transfers, runs, and final disposition. It includes the following information:

Serial numbers of the air flask, afterbody, and tail; mark and mod of the gyro, detonator, and booster; mark and mod of the exercise head or war head and exploder to be used; manufacturer's data on the air flask; dynamometer data and weight; acceptance run data, including the torpedo's rudder throws, speed or speeds, and position of the gyro balance nut; ships or stations to which the torpedo is transferred; air flask chargings, including

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the pressure used each time; record of practice runs, including general conditions, adjustments, and results; record of war shot, including information about the target, the war head and exploder used, and the results; repairs and alterations.

The record book gives the stated speed (or speeds) of the torpedo for water temperature of 62 degrees F. In warmer water it will run faster; in colder water more slowly. A table in the book lists the necessary corrections for sea water temperatures ranging from 30 to 80 degrees F.

Figure 2–4 shows a page from a sample record book. It contains the acceptance run data for a fictitious torpedo, Mk 14 Mod 3A, No. 261100.

After each overhaul of the torpedo, one copy of NavOrd Form 182—torpedo overhauling sheet—is inserted in the record book. This form lists the details of the work done; the men performing and inspecting it; and the drawing number and condition of all the parts that were replaced.

You insert one copy of another from—the torpedo examination report—if you receive a defective torpedo directly from a torpedo station.

Rudtorpe

The Report of Unsatisfactory or Defective Torpedoes or Equipment, NavOrd Form 2333, is called Rudtorpe for short. A filled-in copy of the form is shown in figure 2–5.

BuOrd is responsible for correcting all defects, in either design or materials, in torpedoes and torpedo equipment. Under previous reporting systems, BuOrd had to analyze Repair Part Usage Data, accumulated over a period of time, to find out which torpedo parts were giving trouble. The Rudtorpe program enables the Bureau to do all of the following:

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*SPEEDS CORRECT FOR WATER TEMPERATURE OF 62° F, ACCORDING TO BUORD LETTER DATED 19 APRIL 1944. FOR OTHER WATER TEMPERATURES SEE CORRECTION LIST IN BACK OF THIS RECORD BOOK.

ACCEPTANCE RUNS #261100

Proof Range

Where made Piney Point, Md. Lat. 38.08 N

Height of tube 8'

Depth balance 10 # equals 10 ft.

Rudder throws, horizontal 2 U 4 D

Rudder throws, vertical, upper 20–20 lower 15–15

Impulse charge Oz. SNBP air charge 200 lbs.

Date	9-9-44	
Power	HP	
Flask pressure	2800	
Control valve pressure	580	
Depth setting	15	
Gyro angle	0	
Heel (average)	12L	
Depth (average)	14.5	
Depth, initial dive, ft.	30	
Speed 1,000 yds.	44.04*	
Deflection, in feet	3R	
3500 yds.	45.94*	
	6L	
4500 yds.	46.32*	
	13L	
Ex. Head used, Mk.	30-1	
Head blow setting lbs.	600	
Head blew at	495	

Position of balance nut for static balance in from full out position, turns 1.5

Position of balance nut for running balance in from full out position, turns 1.9

(7)

J. C. Goodnough, Comdr., U. S. N.
Proof Officer

Figure 2–4.—Acceptance run page from a sample torpedo record book.

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REPORT OF UNSATISFACTORY OR DEFECTIVE TORPEDOES OR EQUIPMENT (RUDTORPE)
NAVORD FORM 2333 (REV. 2-55)

REPORT SYMBOL BUORD 8510-2

CLASSIFICATION

TO: U. S. Navy Central Torpedo Office, Newport, R. I.
NOTE: *Fill in all applicable spaces. Use reverse side if necessary.*

REPORTING ACTIVITY	USS STEAMFISH SS 2333 FPO NY	SERIAL NO. 9-55	DATE OF REPORT 2-7-55
REFERENCES	(a) USS STEAMFISH RUDTORPE 10-54 OF 15 AUG 1954		
ENCLOSURES (Photos, Data, etc.)	(1) PHOTOGRAPH OF ORIGINAL DEPTH SETTING OF 40 FEET (2) PHOTOGRAPH OF RECOVERY DEPTH SETTING OF 36 FEET		
MATERIAL IDENTIFICATION	1. MAJOR EQUIPMENT (Name, Mk, Mod): TORPEDO MARK 14 MOD 5	REGISTER SERIAL NO.: 00000	MANUFACTURER: N.T.S. NPT, R.I. — DWG. OR LD. NO.: 255853
	2. ASSEMBLY (Name, Mk, Mod): CONTROL MECHANISM		SERIAL NO. & CODE — DWG. LD. OR STOCK NO.: 287418
	3. PART OR ASSEMBLY (Name): DEPTH SETTER ASSEMBLED		DWG. OR STOCK NO.: 877013
CONDITION FOUND DURING	☐ WATER RUN ☐ DECK TESTS ☐ REPAIR OR OVERHAUL ☐ OTHER ____ ☐ LAUNCHING ☐ SHOP TESTS ☒ INSPECTION		
HOW OFTEN	This item was found 8 times during the course of inspection, repair, overhaul, shop tests, or deck tests of 10 weapons during the period from 1 JAN 1955 to 28 JAN 1955.		

USE THE FOLLOWING GENERAL HEADINGS FOR REPORT BELOW

1. DESCRIPTION OF ITEM OR CONDITION.
2. HISTORY—INCLUDE PAST PERFORMANCE, IF PERTINENT.
3. ANALYSIS—STATE REASON OR OPINION FOR CAUSE.
4. ACTION TAKEN (LOCALLY).
5. RECOMMENDATIONS/REMARKS.

DEFECT, FAILURE, ERRATIC RUN, OR LOSS OF TORPEDO WAS DUE TO

☐ DESIGN ☐ OPERATING PERSONNEL
☒ DEFECTIVE MATERIAL ☐ OTHER (Describe) ____
☐ SHOP PERSONNEL

1. DEPTH SET AND MATCHED AT 40 FEET BY FIRE CONTROL SYSTEM MARK 101 MOD 3 RELAY TRANSMITTER OPERATOR. UPON RECOVERY DEPTH READ 36 FEET.
2. THIS DEFECT WAS PREVIOUSLY REPORTED IN REFERENCE (a).
3. FIRE CONTROL EQUIPMENT OR PERSONNEL ERROR IS CONSIDERED UNLIKELY. DEPTH MAY DRIFT DURING FIRING, RUN, OR RECOVERY.
4. PERSONNEL WERE QUESTIONED AND FOUND COMPETENT. FIRE CONTROL EQUIPMENT TESTED SATISFACTORILY WITH TEST SET MK 21.
5. RECOMMEND THAT DEPTH MECHANISM COMPONENTS BE CHECKED BY DESIGN ACTIVITY TO CORRECT THE DRIFTING OF THE DEPTH SETTINGS.

INFORMATION ON LOST, EXPENDED, OR SURVEYED TORPEDOES	ITEM	MARK	MOD	SERIAL NO.
	EXERCISE OR WAR HEAD			
	EXPLODER			
	PROPULSION BATTERIES			
	PROPULSION BATTERIES			
	DEPTH & ROLL RECORDER			
	ISSUING ACTIVITY			

SIGNATURE OF PERSON DIAGNOSING FAILURE (Optional): Joe Dokes TMC

COUNTER SIGNATURE (Optional)

Figure 2–5.—Rudtorpe, NavOrd Form 2333.

a. correct material defects;

b. prevent potential failures;

c. improve the design, performance, and reliability of torpedoes, self-propelled mines, and equipment in service, in manufacture, and under development;

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d. obtain replacements for defective material from the manufacturer, while the guarantee is still in effect;

e. revise procedures and specifications in BuOrd publications; and

f. maintain accurate, up-to-date inventory records for BuOrd controlled material.

Any Navy activity may originate a Rudtorpe report. When an operating unit transfers a defective torpedo or item of equipment to an overhaul activity, the two should prepare and forward a joint Rudtorpe. If this is not possible, both should submit reports. A Rudtorpe MUST be prepared and forwarded whenever major components of torpedoes and advanced underseas weapons, such as main assemblages, war heads, exercise heads, etc., are surveyed because they're lost, used in warshots, expended, or damaged beyond economical repair.

Prompt and complete reporting is very important. Each defect should be reported as soon as it's found. If the same defect is found more than once, the report should reference the previous reports on that defect.

Report of Completion of an OrdAlt

The Bureau of Ordnance has adopted the following procedure, to be followed every time an OrdAlt is completed:

1. The completion of each OrdAlt will be reported to the Bureau of Ordnance and the administrative type commander on the *Report of Completion Card* (NavOrd Form 1215) supplied for that purpose.

2. For ships in commission, the report will be made by the commanding officer, regardless of whether the OrdAlt was performed by naval shipyard, tender, or ship's force.

3. For ships not in commission, the report will be made by the commandant of the naval shipyard effecting the OrdAlt.

4. OrdAlts are often issued which are applicable to new ships, but which, through lack of funds, time, or

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material, are not accomplished by the building or fitting-out yard. When the ship is commissioned, the commandant should deliver to the commanding officer such uncompleted OrdAlts, together with all plans and material. The commanding officer will complete the OrdAlt as soon as practicable, and make the required reports.

Current Ship's Maintenance Project (CSMP)

The Current Ship's Maintenance Project and Alteration and Improvement file (SCMP and A&I) is a record of alterations and repairs to be performed at some future date, usually when the ship is alongside a tender or during a yard overhaul. It is a record of all jobs that can not be completed while the ship is in a normal operating status.

If no records were kept, many repair jobs would probably be overlooked when it came time to prepare the work and alteration requests for submission to a repair ship or naval shipyard. This does not mean that CSMP cards are made out only for work to be done by these activities. They are for any work, whether for ship's force or naval shipyard, that requires the ship to be inoperative.

It is advisable to study the system in use on your ship. You may be required only to report alterations and repairs that cannot be done while the ship is operative, or that require the services of specialized personnel available on tenders or in shipyards. On the other hand, you may be given responsibility for the complete file.

Since all CSMP files are kept for the same purpose, all the various systems in use are basically similar. The following information should be shown on all CSMP cards:

1. Name of ship, and date the card was made out;
2. Bureau under whose cognizance the work falls;
3. Class of work: desirable repairs, urgent repairs, or alterations;

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4. Description of work (clearly and definitely stated);
5. Exact location of the defective unit or equipment.

Under the heading of "Torpedo Equipment", the work should be split into three classes: (1) alterations, (2) repair work to be done by the Naval shipyard, and (3) repair work to be done by the ship's force. The alterations card will show who is to do the work. It will show the information required to make up the work request for the alteration, and will give any reason why the alteration has not been made or can not be accomplished. Most of the alterations listed on the card will, of course, be OrdAlts.

However, it often happens that an individual ship will originate plans for a special alteration. In this case these plans and all other pertinent information concerning the alteration should be entered on the card and filed, awaiting approval of the Bureau of Ordnance. Such alterations will not be called OrdAlts, since they will be authorized specifically by letter from the Bureau of Ordnance, and will apply to one ship only, or to a limited number of ships on a more or less experimental basis.

The card for shipyard repair work should show the class of work (urgent or desirable), and all information required to make up the work request. The card for repair work by ship's force should contain the same information as the repair card for the naval shipyard.

You will find further information on the CSPM in Chapter 6, Section IV, of the *BuShips Manual.*

Work Request for Repairs and Alterations

The word "repairs" refers to any work that may be necessary to restore equipment to serviceable condition without alteration of design, addition of parts, or removal of any parts not to be replaced.

"Alterations" are all work not included in the definition of repairs, including any changes in design that seem advisable in making repairs. It also includes all addi-

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tions of parts, all removal of parts not to be replaced by similar ones, and all changes in the material of which any part is made. No alteration should be made to any ordnance equipment or parts thereof, either by the ship's force or by a naval shipyard, until specifically authorized by BuOrd.

Work requests for repairs are classified either as "urgent" or "desirable." "Urgent repairs" include all repairs necessary for cruising, military efficiency, preventive maintenance, or for sanitary reasons. "Desired repairs" include all repairs that should be made when the services of the ship can be spared long enough to do the work.

Work requests are made by official letter to repair ships and naval shipyards. The procedure for requesting the services of a repair ship is more informal than that required for naval shipyards; these work requests can be submitted by dispatch if necessary. Requests to a repair ship are made when the work is beyond the ability of the ship's force, but does not require the services of a naval shipyard.

A dispatch requesting the services of a repair ship should contain:

1. Item of work clearly and definitely stated;
2. Exact location of the defective unit or equipment;
3. Amount and nature of the repairs required;
4. Reference to blueprints and identification marks.

An official letter requesting repairs or alterations from a naval shipyard should contain:

1. Name of ship, date, and place from which the letter is sent;

2. Bureau under whose cognizance the work falls;

3. Class of work: desirable or urgent repairs, or alterations;

4. Item of work clearly and definitely stated, location of defective parts outlined in detail, and amount and nature of the repairs required;

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NOTE: If it is essential to a clear understanding of the request, include sketches of the proposed work. Refer, where necessary, to blueprint numbers and identification marks. Requests that are general in nature or vague in character will not be considered as complying with the above requirements.

5. A statement that the work is not within the power of the ship's force to perform.

Work requests to a naval shipyard must be approved by the type commander and a committee at the yard. After approval, the request is used to make up a job order. The job order covers the time required, cost, material, and the necessary prints to be used in the performance of the work. A list of the approved job orders is supplied to the ship when it arrives in the yard.

Disapproval of a request usually means that the type commander or the yard believes that the work requested is within the scope of the ship's force.

During a yard overhaul or repair period alongside a tender, the responsibility that all alterations and repairs be made properly lies primarily with the men in charge of the equipment. If you are in charge of the torpedo equipment, it is up to you to get a list of the job orders to be accomplished. As the work progresses, follow up each job order and inspect the work. You may even be responsible for giving the final OK on the work. In the event of faulty workmanship, or work that will not be completed according to schedule, notify the division or gunnery officer so that he can take official action.

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QUIZ

1. BuOrd requires up-to-date information on the performance and maintenance history of all the weapons in the fleet. What is its principal source of this information?
2. What three types of paper work are you most likely to be concerned with?
3. In what publication can you find detailed information on the Navy supply system?
4. Give brief definitions of "producer logistics" and "consumer logistics".
5. What organization serves as the supply office for major ordnance equipment with high security classification?
6. What is the principal difference between supplies and equipage?
7. What are allowance lists?
8. Who makes up the allowance lists for ordnance materials?
9. Name two different ways to order Navy material.
10. Who must approve an in-excess requisition before it can be filled?
11. What two forms will you probably use to order torpedo parts?
12. How can you obtain material that is in the custody of the storekeeper?
13. When you use material that is in the custody of your department head, what form must be filled out?
14. If an item of equipage is in your custody, and you turn it over to someone else, what precaution should you take?
15. What is a survey?
16. What is the Torpedo Log?
17. What is the Torpedo Record Book?
18. What is the CSMP?
19. Who reports completion of an OrdAlt for a ship not in commission?

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CHAPTER 3

REVIEW OF THE AIR-STEAM TORPEDO

In this chapter, we're going to review the Navy's four air-steam torpedoes—the Mks 13, 14, 15, and 23. We'll run through a short description of the principal parts and systems, and a short outline of their operation. All this will probably seem like old stuff to you. It should. You've been through it many times before. Before you advanced to TM 3 or TM 2, you had to learn the nomenclature of torpedo parts, and the principles of torpedo operation. You probably learned them thoroughly. Since then, you've had plenty of opportunity to put your knowledge to practical use.

Why go through all that again? There's a very good reason. Think back to your early days in the TM rating. What did you do when you came to a problem you couldn't solve by yourself? You took it to one of the senior PO's. Maybe you still take some of your tougher problems to the TMC. As you advance in rating, you will have more and more men under your supervision. These men will be bringing their problems to you. You will be the man with all the answers. And you'll want to have them on the tip of your mind—not somewhere in the back of your memory.

Torpedoman's Mates, as they advance in rating, tend to specialize. If you've been assigned to a repair shop, you may have spent most of your time on one particular part

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of the torpedo. You may even have specialized on one part of one mark of torpedo. Of course you know all about the other parts, and the other types, but you haven't been using your knowledge. Unused information tends to get rusty. Maybe it's time to overhaul your elementary knowledge of torpedoes.

Here's what we suggest. Read through this chapter quickly. If it all seems easy and familiar, you're in good shape. If you run into ideas you're hazy about, your information is rusty. You need a more thorough review than you can get from this chapter. Read the appropriate chapters in the training course for Torpedoman's Mate 3&2. You may have studied the old, one-volume course. The course for 3&2 was republished in 1955, in two volumes. Be sure you get the new one—NavPers 10155 and 10156.

The training courses can give you only general information. Remember that for specific information you'll have to go to the OP's and the Ordnance Drawings.

The information you will review in this chapter is part of the qualifications for advancement to TM 3 and TM 2. It is not a part of your quals for advancement to TM 1 or Chief. To help you decide how much of a review you'll need, here's a good rule. Remember that you have to know everything the lower rates know about torpedoes. Only you have to know it better.

OVER-ALL VIEW

The torpedo is a self-propelled underwater weapon, designed to carry a charge of explosive to an enemy ship and detonate it there. Propelling mechanisms are of two types: steam turbine engines, and electric motors. Every torpedo must carry its own supply of energy. Electric torpedoes carry energy in storage batteries. The torpedoes powered by a steam turbine carry energy in the form of compressed air and alcohol. In the so-called CHEMICAL TORPEDOES, oxygen for burning the fuel

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is provided by NAVOL, a strong solution of hydrogen peroxide in water.

After launching, the torpedo seeks the depth for which its depth mechanism has been set, and maintains that depth throughout its run. It turns itself onto the course for which its steering mechanism has been set, and maintains that course. Two types of torpedoes—Mks 14 and 15—offer a choice of speeds; the speed-change mechanism must be set for the desired speed before the torpedo is launched. Thus every torpedo has at least two INPUTS—depth and gyro angle—which must be preset. In the older torpedoes, both air-steam and electric, you apply these settings by turning sockets in the outer shell of the torpedo. This is done mechanically, by mechanisms mounted on the torpedo tube. In the newer torpedoes, all three of these inputs are electrically set, through a cable. The electric setting mechanisms are classified; we'll describe them in volume 2 of this course.

The torpedo war head, which carries the explosive charge, is fitted with an exploder mechanism. This device has two jobs to do. It must keep the war head safe, so that detonation will be impossible until the torpedo has reached a safe distance from the firing ship. When the torpedo reaches the enemy ship, the exploder must detonate the main charge in the war head. During the first part of the torpedo run, the exploder arms itself and becomes operable. The arming action is mechanical; the exploder mechanism rearranges some of its parts so that detonation of the main charge becomes possible. In addition, some exploders are provided with an electrical arming feature.

In general, exploder mechanisms may be divided into two types: those that operate by INERTIA, and those that operate by INFLUENCE. The inertia or contact exploder operates only when the torpedo gets a sudden jolt, as it does when it strikes the hull of a ship. The influence exploder operates when the torpedo passes close to a ship,

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even without direct contact. We will describe the current types of contact exploders in chapter 7 of this volume; the influence exploders are covered in volume 2.

TYPES IN SERVICE

It would be handy for Torpedoman's Mates if all the torpedoes in the fleet were exactly alike—if we had only one mod of one mark in service. At present, we have a number of different types, and a few of them have more than one use. Some of them may be fired either from a surface ship or a submarine. The Mark 13 may be dropped from an aircraft or launched from a torpedo boat. Other types are designed to do one specific job.

Each type of torpedo has its own advantages and disadvantages. For example, an electric torpedo is slow compared with the air-steam type. But an electric torpedo leaves no wake. A wakeless torpedo is extremely valuable when a submarine attacks a surface ship, because it does not reveal the sub's position. In a surface-to-surface engagement, speed is an all important factor. In any attack against a submerged submarine, a homing torpedo has an obvious advantage. But homing mechanisms are best suited to electric torpedoes, which are relatively slow; and the homing mechanism takes up space that might otherwise be filled with explosive. For these reasons, a homing torpedo probably isn't the best bet when one destroyer attacks another. As you can see, there is a need for different kinds of torpedoes to do different jobs.

Electric Torpedoes

Since electric torpedoes leave no wake, and can be produced cheaper and faster than air-steam torpedoes, they are in many ways the most practical kind for submarine service. Most of the homing torpedoes are powered by electric motors. The Navy issued its first electric torpedo—the Mk 18—to the Fleet in 1943. In spite of its length of service, the Mk 18 is still unfamiliar to some Torpedoman's Mates. If you haven't had a

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chance to work with the Mk 18 torpedo, we suggest that you give it special study now. We'll review it in some detail in chapter 8 of this volume. Homing torpedoes are covered in volume 2.

Chemical Torpedoes

The chemical torpedoes now in use in the fleet—those of the Mk 16 type—are fired from submarines. In basic principles, Mk 16 torpedoes are much like those of the air-steam type. Both are driven by turbines which are spun by the pressure of superheated gases.

In the air-steam torpedo, compressed air provides oxygen for burning the fuel. In the Mk 16, oxygen is provided by the NAVOL CYCLE. "Navol" is the Navy name for a highly concentrated solution of hydrogen peroxide (H_2O_2). This hydrogen peroxide is chemically the same as the kind you can buy—in a much weaker solution—at the corner drugstore, for use as a mild antiseptic or for changing brunettes into blondes.

Before it enters the combustion pot of the Mk 16 torpedo, the navol passes through a decomposition chamber. There it's forced through screens coated with a chemical catalyst. The catalyst decomposes the navol into oxygen and water. Because this reaction produces a tremendous quantity of heat, the water is released in the form of superheated steam.

When alcohol burns in oxygen, as it does in navol torpedoes, it makes a much hotter flame than when it burns in air (as it does in the Mk 13, 14, 15, and 23). To keep the temperature within bounds, additional water is sprayed into the oxygen-steam mixture before it enters the combustion pot.

The gases that drive the turbine are carbon dioxide (from the alcohol) and steam (from three sources—the alcohol, the water spray, and the navol). The steam in the torpedo's exhaust condenses almost as soon as it leaves the torpedo. Carbon dioxide dissolves easily in water, and most of it dissolves before it can reach the surface.

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The Mk 16 has other advantages too. The navol cycle releases a lot of power in a small space. And the Mk 16 needs no compressed air, except to operate the control mechanisms and to force the fuel, water, and navol out of their storage tanks. The space this saves is used in two ways: (1) To carry extra fuel and navol to give the torpedo more range and speed; (2) To carry a much bigger payload of explosive in the war head.

Current mods of the Mk 16 torpedo are classified; we will describe them in volume 2.

Air-Steam Torpedoes

Although chemical and electric torpedoes are reaching the fleet in increasing numbers, the air-steam type is still important. It's by far the most familiar type.

As we mentioned earlier, the latest torpedoes have electric setting mechanisms for gyro angle, depth, and speed. These are the marks and mods of MECHANICALLY SET air-steam torpedoes now in use:

Mk 13 Mods 6 through 13 Launched from aircraft or PT boats. Length, 13.5 feet; diameter, 22.5 inches. Weight, 2,216 pounds. Speed, 33.5 knots. Range, 4,000 yards.

Mk 14 Mod 3A. Launched from submarines. Length, 20.5 feet; diameter, 21 inches. Weight, 3,280 pounds. Two speeds and ranges: 9,000 yards at 31.5 knots, or 4,500 yards at 46 knots.

Mk 15 Mod 3. Launched from destroyers and destroyer escorts. Length, 24 feet; diameter, 21 inches. Weight, 3,841 pounds. Three speeds and ranges: 15,000 yards at 26.5 knots, 10,000 yards at 33.5 knots, or 6,000 yards at 45 knots.

Mk 23 Mod 1. Same as Mk 14 Mod 3A, but without the speed-change mechanism. It operates only in high speed.

Because the other types are discussed elsewhere in this course, the rest of this chapter applies only to the torpedoes listed above.

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SECTIONS OF A TORPEDO

In general, the outer shell of an air-steam torpedo is composed of five sections. They are, from fore to aft, the head section, air flask section, midship section, afterbody, and tail. The head section may be a war head, an exercise head, or a war-exercise head. The midship section is sometimes not counted as a separate section because it's permanently attached to the air flask section. Figure 3–1 shows the four principal sections of a Mk 13 type torpedo.

Torpedoes are issued to the Fleet in only three sections. The air-flask and midship sections, of course, are permanently joined. In addition, the afterbody and tail

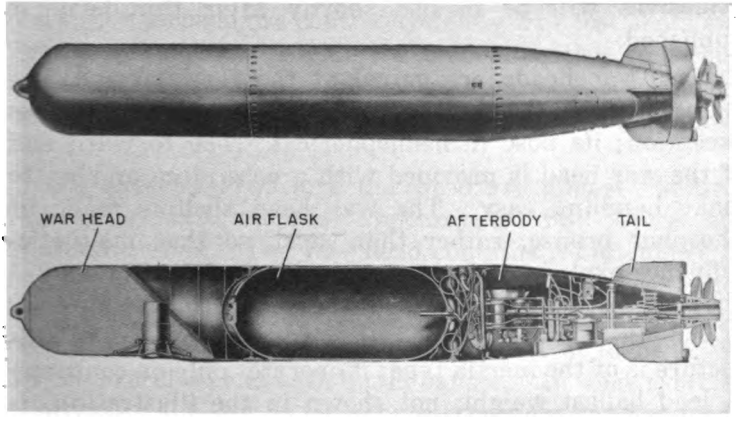

Figure 3–1.—Sections of a Mk 13 type torpedo.

sections are assembled together before shipment. This makes shipment simpler, and makes it easier to keep all the units of one torpedo together. Even so, some of the smaller sections and mechanisms may get separated from the rest of the torpedo when large numbers of torpedoes are shipped together. We suggest that when you're in charge of handling a large shipment, you take every possible precaution to keep it organized.

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War Head

In order to destroy an enemy ship by damaging its hull, the torpedo must carry a heavy charge of high explosive. The war head section carries both the explosive charge and the exploder mechanism that detonates it. Each type of war head is designated by mark and mod numbers. The OP that describes each torpedo tells which war head is used with it. The mark and mod of the war head may be the same as those of the torpedo; often they are different.

Torpedo war heads were formerly filled with TNT, torpex, or a mixture of the two. The explosive charge used at present is HBX. It is very likely that newer explosives will be in use shortly after this book is published.

Most war heads are ogival at the forward end and cylindrical in the after portion. The Mk 13 is an exception; its nose in hemispherical. The forward end of the war head is provided with a nose piece or ring to make handling easy. The war head shell is made of phosphor bronze, rather than steel, so that magnetic-influence exploders may be used effectively. Figure 3–1 shows a sectional view of the war head for an early mod of the Mk 13 torpedo. (The exploder mechanism in this picture is of the inertia type; it operates only on contact.) A lead ballast weight, not shown in the illustration, is mounted in the lower part of the war head to help the torpedo run with the proper trim.

Normally, war heads are stowed with the exploder mechanism removed. They don't need much attention, except for routine inspection to keep them from getting rusty or otherwise damaged by the weather. If, in the future, war heads containing TNT are issued, it will be necessary to inspect them frequently for TNT exudate. The exudate will leak out if the bulkhead joint is faulty. It must not be permitted to collect in a stowage space.

Each war head is provided with a steel protecting ring.

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This ring is installed on the after end of the head, and forms a protective base for it while it's being shipped or stowed. It will be your job to see that no war head is stowed—especially in a vertical position—without its protecting ring. Otherwise, any sudden shock or jar to the flange at the after end of the war head might make assembly of the head to the air flask difficult or impossible.

Exercise Head

Every torpedo, before it's issued to the Fleet, must undergo one or more test firings. In the Fleet, it may go through a series of "exercise shots," to give the torpedo crew actual practice in launching torpedoes, and to test the ship's torpedo fire control system. For test shots and exercise shots, we provide the torpedo with an exercise head rather than a war head. Figure 3–2 shows a cutaway view of Exercise Head Mk 26 Mod 3, designed for use with Mk 13 torpedoes.

The exercise head and war head are almost identical in shape and outside appearance. But there the similarity ends. The war head contains a big charge of explosive, and an exploder mechanism. The exercise head has neither. So that an exercise torpedo will have the same fore-and-aft balance as a war shot torpedo, we fill the exercise head with liquid ballast. In some exercise heads we use water as ballast; in others we use a solution of a chemical, usually calcium chloride, in water. The OP for each torpedo will tell you what solution to use for ballast, and how to mix it.

A war shot torpedo has negative buoyancy: it weighs more than an equal volume of water. For that reason a war shot torpedo, if it misses its target, will sink when it comes to the end of its run. In order to simulate a war shot as closely as possible, an exercise torpedo must also start its run with negative buoyancy. But it must have positive buoyancy after the end of its run, so it will float until we can recover it. We solve that problem by

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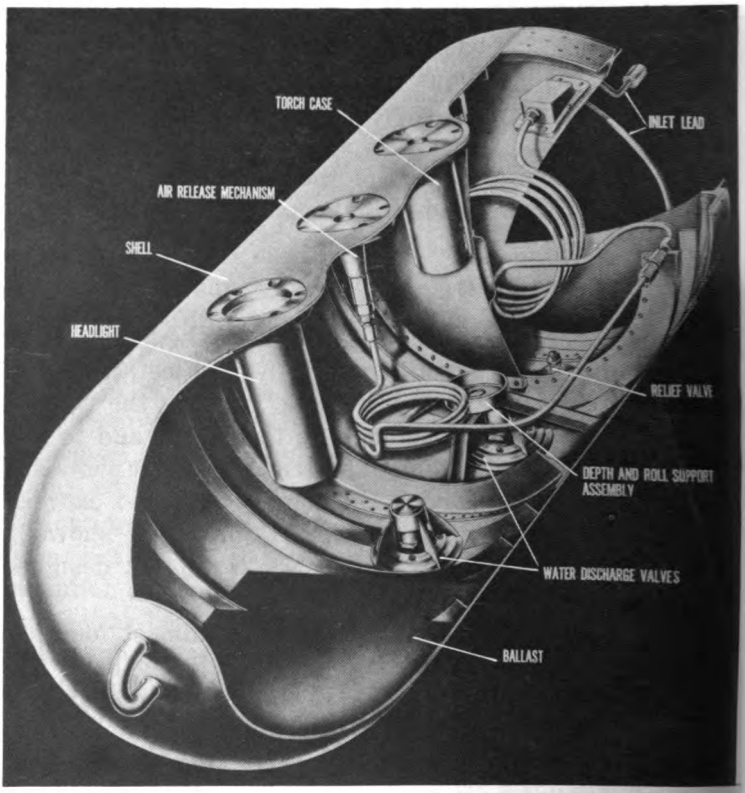

Figure 3–2.—Exercise Head Mk 26 Mod 3, cutaway view.

making the liquid ballast expendable. The exercise head is designed to get rid of the liquid ballast at the proper time.

As you can see in figure 3–2, an AIR-RELEASE MECHANISM is mounted on a flange at the top of the exercise head shell. The mechanism is supplied with air from the torpedo air flask, through a coiled copper pipe. Figure 3–3 is a sectional view of the Mk 3 air-releasing mechanism. Its principal part is a spring-loaded valve. Spring pressure tends to hold the valve open, so that air from the copper pipe can flow freely into the exercise head

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cavity. But when you connect the pipe to the torpedo air flask, air at flask pressure overcomes the pressure of the spring, and holds the valve shut so that no air can escape.

As the torpedo uses air from the air flask during its run, the flask pressure gradually drops. When it falls low enough—somewhere between 400 and 900 psi—it can no longer overcome the spring pressure in the release mechanism. Then the valve opens and air from the flask

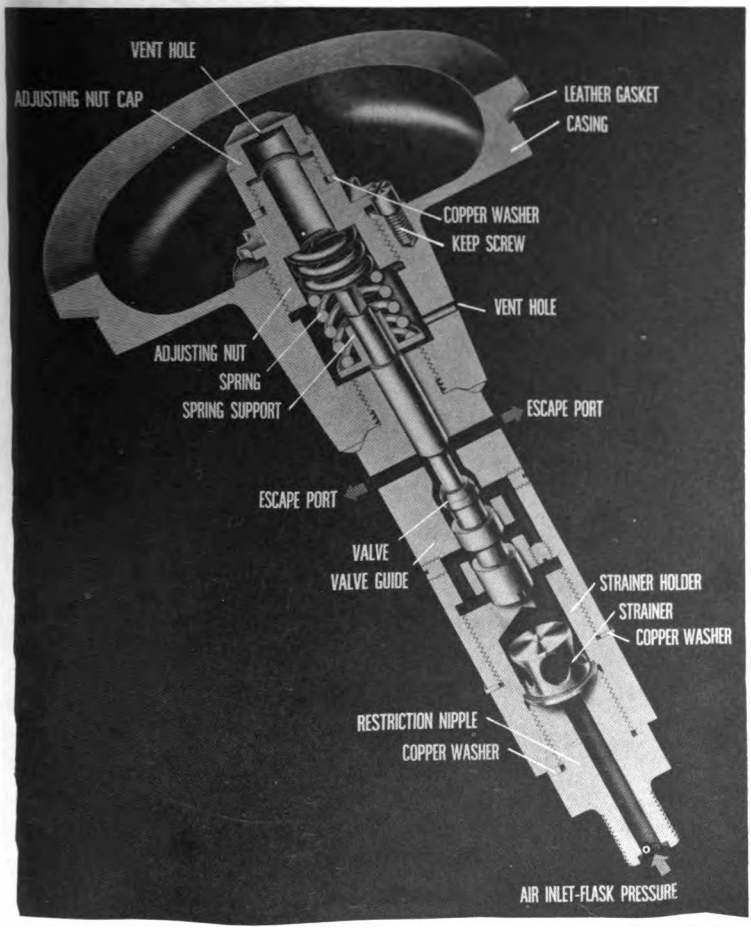

Figure 3–3.—Sectional view of Air-releasing Mechanism Mk 3.

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flows through the mechanism and into the exercise head, forcing the liquid ballast out through the discharge valve in the bottom of the exercise head shell. The discharge valve opens outward. Because its spring tends to hold it shut, it will open only when the pressure inside the head is somewhat higher than the pressure outside. Thus the liquid ballast can be forced out through the discharge valve, but no sea water can enter the exercise head through it. Figure 3–4 shows an exploded view of the discharge valve of a Mk 13 torpedo.

The three diagrams in figure 3–5 summarize the ballast-expulsion feature of the exercise head.

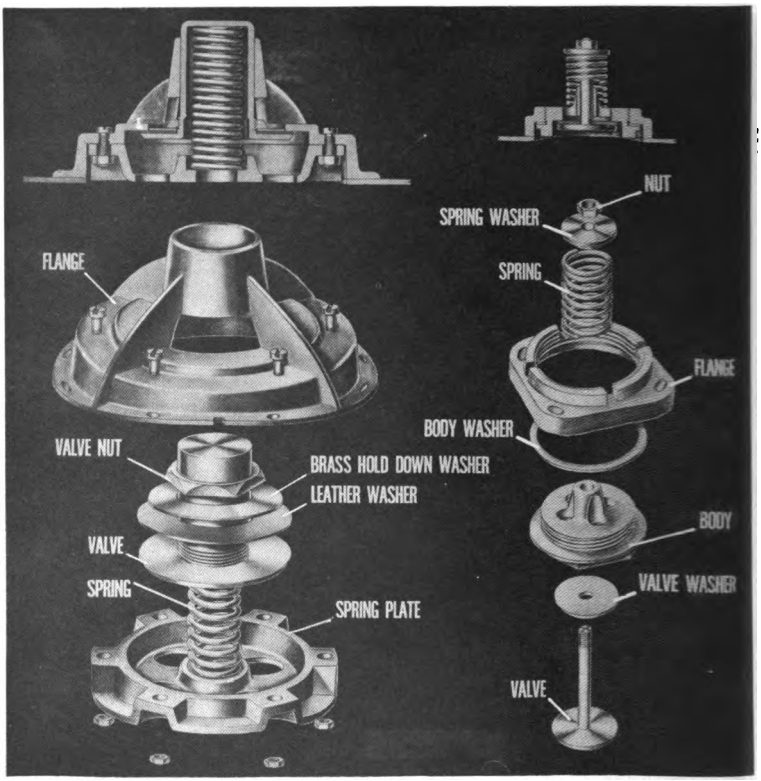

Figure 3–4.—Water discharge valve, exploded view.

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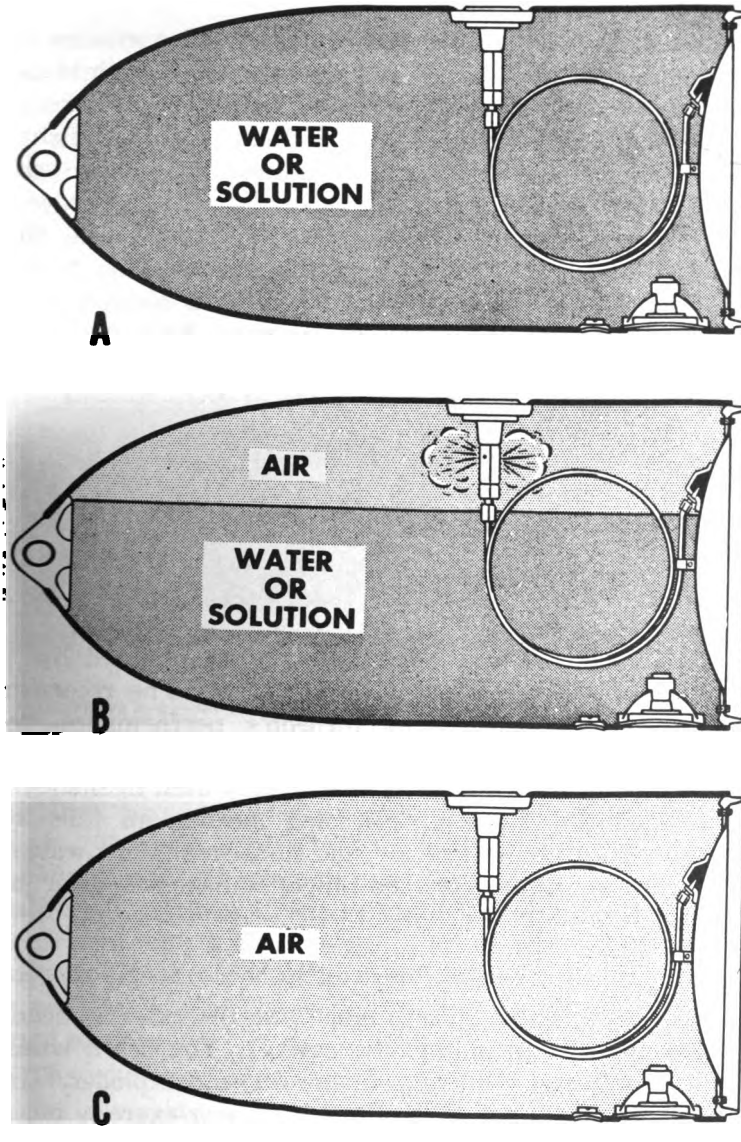

Figure 3–5.—Operation of the ballast-expulsion feature.
A. Exercise head at start of run.
B. Exercise head with ballast being expelled through discharge valve.
C. Exercise head blown.

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As shown in figure 3–2, the exercise head may also be provided with a headlight and a torch case. Both these features make the torpedo easier to find after an exercise run. The headlight, of course, is most useful at night; the torch is used for daylight firings. The headlight consists of a small lamp powered by dry cells, or by wet cells of the same size. An inertia switch turns the headlight on at the instant of firing. The torch case contains a chemical—usually calcium phosphide—that burns and smokes when it gets wet. You break the seal of the torch case shortly before firing the torpedo. You will usually use a small piece of soap to seal the opening temporarily. The soap dissolves as the torpedo moves through the water, so that the torch begins to operate before the torpedo reaches the end of its run. Here's a point to remember. The torch is considered a fire hazard when loaded in the bomb bay of an aircraft. Don't use a torch in an aircraft torpedo unless you have special permission.

Either the torch or headlight may be replaced by a depth and roll recorder, or by a pinger. The recorder helps you to analyze the torpedo's performance by providing a graphic record of the running depth and angle of roll. The pinger is occasionally used in shallow-water firing. If the air-releasing mechanism fails to operate, and the exercise torpedo sinks in shallow water, the pings of sound from the pinger will help a diver to locate the torpedo.

War-Exercise Head

The war-exercise head is much like the exercise head, except that it has an exploder cavity. You use it when you want to test the action of the torpedo exploder. In one of the openings at the top of the war-exercise head shell, you mount a case that contains a number of brightly colored plywood disks and a small charge of explosive. When the exploder operates, it detonates this small charge of explosive. The plywood disks are blown out into the

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water, where they float and indicate the point at which the exploder functioned.

Air-Flask Section

In an air-steam torpedo, the air flask itself almost completely fills the air-flask section. Figure 3–6 is a cutaway view of the air-flask and midship sections of a Mk 15 torpedo. Note that the flask is relatively longer than it's shown in the illustration; part of the picture has been cut out near the left-hand edge.

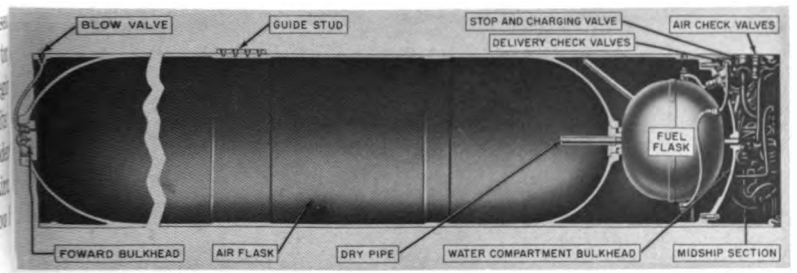

Figure 3–6.—Air-flask section of the Mk 15 torpedo, cutaway view.

A small removable bulkhead at the forward end of the air flask provides access for cleaning the inside of the flask. The copper pipe that takes air to the air-releasing mechanism in the exercise head is attached to this small bulkhead. Before it enters the head section, this pipe passes through a blow valve. For a war shot, the blow valve is closed. For an exercise shot, you open the blow valve after you've connected the pipe that leads into the head section.

The after end of the air-flask section is closed by the water compartment bulkhead. The water compartment consists of the space between this bulkhead and the after end of the air flask. Inside the water compartment is the doughnut-shaped fuel flask. The main air pipe passes from the air flask, through the central opening in

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the fuel flask, to a connection in the center of the water compartment bulkhead.

Midship Section

In the air-steam torpedoes, the midship section is a forged ring riveted and soldered to the after end of the air flask section. The after end of this ring is machined to form a joint with the torpedo afterbody. The midship section is closed at its forward end by the water compartment bulkhead of the air-flask section. In the

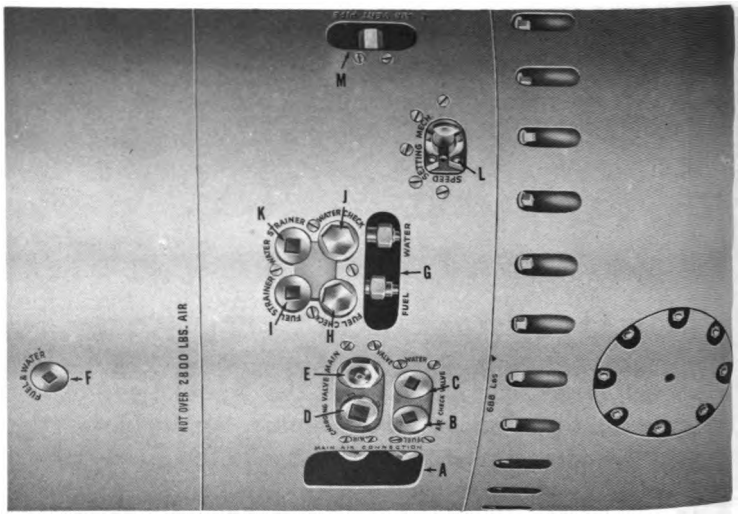

Figure 3–7.—Midship section of a Mk 15 type torpedo, top view. A. Access hole (permits connection of air pipe to air-check valves and main air connection to starting valve after assembly of afterbody to air flask. B. Air-check valve (fuel). C. Air-check valve (water). D. Charging valve. E. Stop valve. F. Water-filling plug. G. Access hole to fuel and water connections to check valves. H. Fuel-check valve. I. Fuel strainer. J. Water-check valve. K. Water strainer. L. Speed-setting mechanism socket. M. Access hole to vent fitting.

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assembled torpedo, it's closed at its after end by the turbine bulkhead of the afterbody.

Mounted on the shell of the midship section are a number of valves and fittings associated with the air and superheating systems. We'll discuss them later. They include the stop and charging valves, the fuel and water strainers and check valves, and the air-check valves. Access to these fittings is available through labeled openings in the midship section shell. (See fig. 3–7.) Through these openings, sea water enters and fills the midship section during the torpedo run, thus helping to prevent overheating of the combustion flask and its related parts.

Afterbody

The forward end of the afterbody is cylindrical; it curves gently into the truncated cone of the after end. At the after end it's closed by the afterbody bulkhead; at the forward end by the turbine bulkhead. Inside the afterbody section, and on the forward face of the turbine bulkhead, are the torpedo's propelling and controlling mechanisms. These mechanisms start the torpedo, convert its stored energy into the power that drives it from firing ship to target, and control its course and depth throughout the run. Figure 3–8 shows a torpedo afterbody mounted on an afterbody adjusting stand.

Mounted on the forward face of the turbine bulkhead are the starting and reducing valves (in a single housing), the combustion flask and igniter, and the nozzle valves through which the combustion gases pass to the turbines. The two turbines, one above the other, are on the other side of the bulkhead. They are mounted on concentric vertical spindles. Gears on the turbine spindles, through the gears of the main engine, turn the two propeller shafts—one inside the other—in opposite directions. These shafts pass through a bearing in the afterbody bulkhead, into the tail section.

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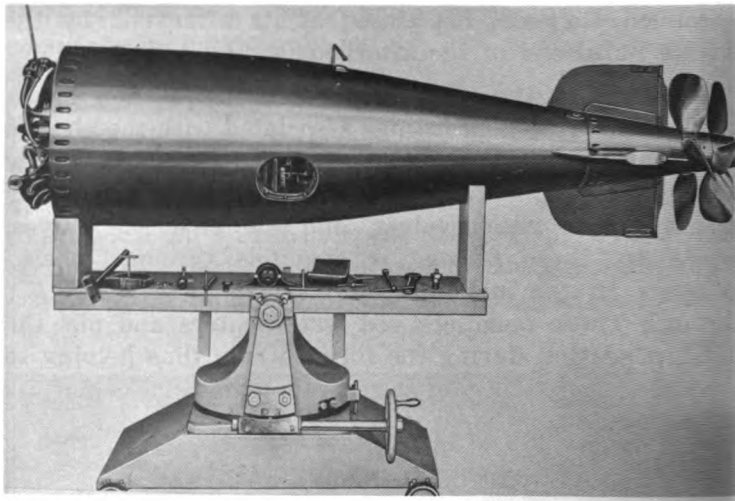

Figure 3–8.—Afterbody on an afterbody adjusting stand.

Also included within the afterbody are three parts of the air system—the starting gear, the control valve, and the preheater.

Mounted on a separate assembly in the bottom of the afterbody are the two control mechanisms. The gyro and its associated steering mechanism turn the torpedo onto its present course, and hold it there. The depth mechanism brings the torpedo to its present depth and keeps it there. Steering and depth orders from the two control mechanisms are transferred to the steering and depth engines. Both these engines are powered by compressed air. The steering engine operates the vertical, or steering rudders, and the depth engine operates the horizontal, or depth rudders, by means of rudder rods that pass through packings in the afterbody bulkhead.

Tail Section

The torpedo tail section is a short, truncated cone. It carries the surfaces that drive the torpedo through the

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water—the two propellers, and the surfaces that control its path—the tail blades and rudders. In an air-steam torpedo, each of the two propellers has four blades. The two propellers turn in opposite directions. The rotation of a single propeller would set up a gyroscopic force that would make the torpedo hard to steer, and a twisting force that would tend to make it roll. The gyro actions and twisting forces of two counterrotating propellers cancel each other.

The tail blades stabilize the torpedo as it moves through the water, and help to keep it pointed in the right direction. The vertical rudders, by turning to left or

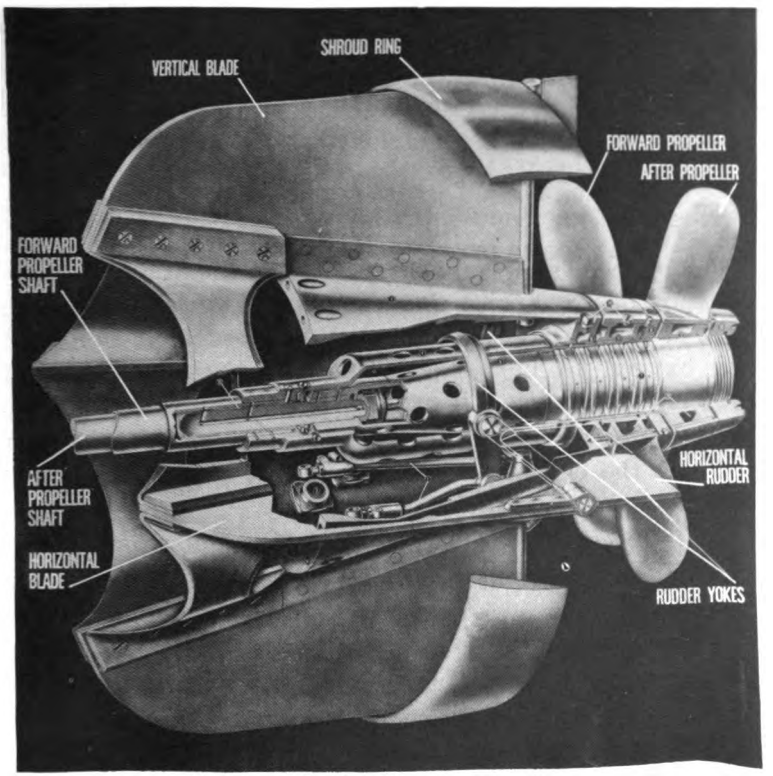

Figure 3–9.—Tail section, cutaway view.

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right, control the torpedo's course; the horizontal rudders, by turning up or down, control its depth. Each pair of rudders is connected to the appropriate rudder rod by a semicircular yoke, which changes the fore-and-aft motion of the rod to the turning motion of the rudder.

Figure 3–9 shows a cutaway view of the tail section of a Mk 13 torpedo. Each propeller is mounted on a propeller hub; each of the two drive shafts is connected to one of the propeller hubs by a hollow, perforated propeller sleeve. As you can see in the illustration, the outer propeller shaft and sleeve turn the forward propeller. The inner shaft and sleeve turn the after propeller.

Exhaust gases from the turbines pass into the hollow tail section through exhaust valves in the afterbody bulkhead. They pass through the perforations in the two propeller sleeves, and leave the torpedo abaft the afterpropeller hub.

AIR SYSTEM

The torpedo's air supply is stored in its air flask, at a pressure of 2,800 psi. This compressed air holds a large part of the energy that propels the torpedo. It supplies the oxygen to burn the alcohol in the superheating system. In addition, it provides energy for a number of miscellaneous jobs:

1. At the end of an exercise run, it blows the liquid ballast out of the exercise head.

2. It forces fuel and water into the combustion flask.

3. It operates the igniter that starts the air-fuel mixture burning.

4. It operates the starting valve, which puts all the propelling and control mechanisms of the torpedo into operation.

5. It operates the gyro spinning and unlocking mechanism, which gives the gyro its initial spin and brings it up to full speed.

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6. It keeps the gyro spinning during the whole torpedo run.

7. It supplies energy for the depth and steering engines, which operate the horizontal and vertical rudders.

Figure 3–10 is a schematic diagram of the air system. It isn't supposed to show the actual appearance or location of the parts, but it does show how they're connected. Check back to this diagram frequently as you study the following discussion.

By means of the stop valve, you can shut off the air flask from the rest of the torpedo air system. You charge the flask through the charging valve. Both these valves are in a single housing, secured to the upper part of the midship section shell. Figure 3–11 shows both a sectional and an exploded view of the stop and charging valve assembly of a Mk 13 torpedo.

Look at the sectional view in the upper part of figure 3–11. The opening at the right is connected to the air flask. When the stop valve is closed, the air flask is shut off from the charging valve as well as from the rest of the air system. When the stop valve is open, as it is in the illustration, air can flow freely around the charging valve spindle, and out through the opening at the left. From there it goes to the starting valve on the turbine bulkhead.

To charge the air flask, you remove the charging-valve plug and screw in the tip of the charging fitting. This fitting unseats the spring-loaded charging valve. After you open the stop valve, and the valve in the charging line, air can flow in to charge the flask. It will also flow to the starting valve. But it will get no farther; the starting valve stays closed until the starting gear is tripped. If it has been a long time since you've had actual experience in charging an air flask, it would be a good idea to study the step-by-step directions in one of the OP's. You will be supervising this operation, and enforcing the safety

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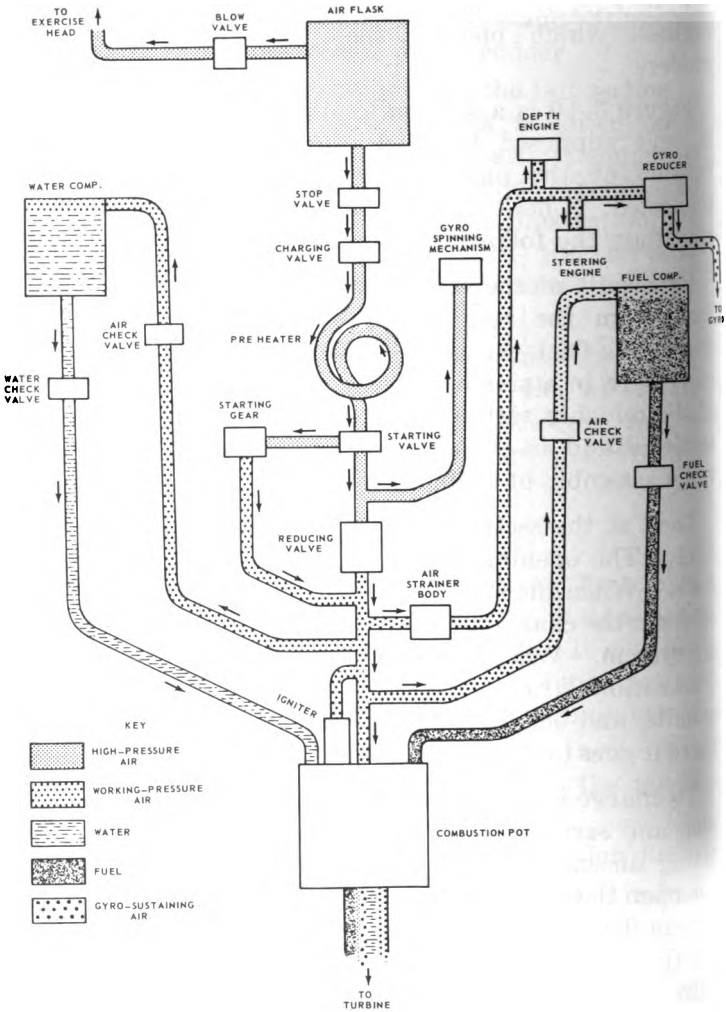

Figure 3–10.—Schematic diagram of the air system.

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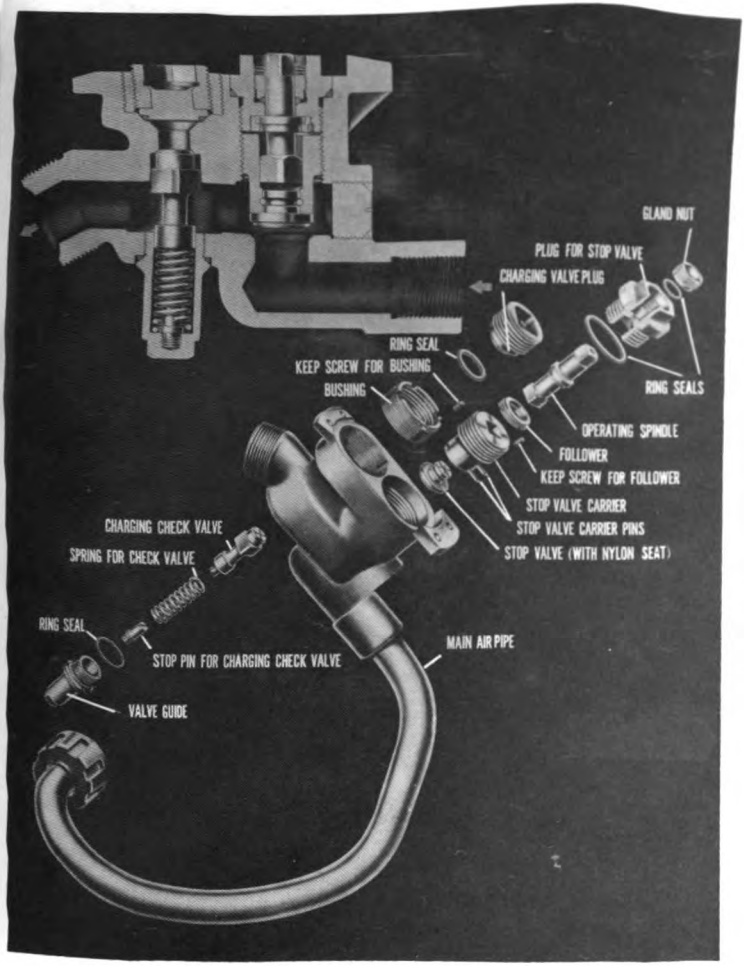

Figure 3–11.—Stop and charging valves of a Mk 13 torpedo.

precautions is an important part of your job. We don't have to tell you that compressed air at 2,800 psi is extremely dangerous. With careless handling, it's more likely to cause a serious accident than the high explosive in the torpedo war head.

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Figure 3–12 shows the starting, reducing, and restriction valve group of a Mk 15 torpedo. This assembly is mounted on the forward face of the turbine bulkhead. The main air pipe takes flask-pressure air from the stop and charging valve assembly, through the preheater, and into the fitting shown at the left edge of the diagram in figure 3–12. The preheater is simply a double loop of pipe, located in the path of the turbine

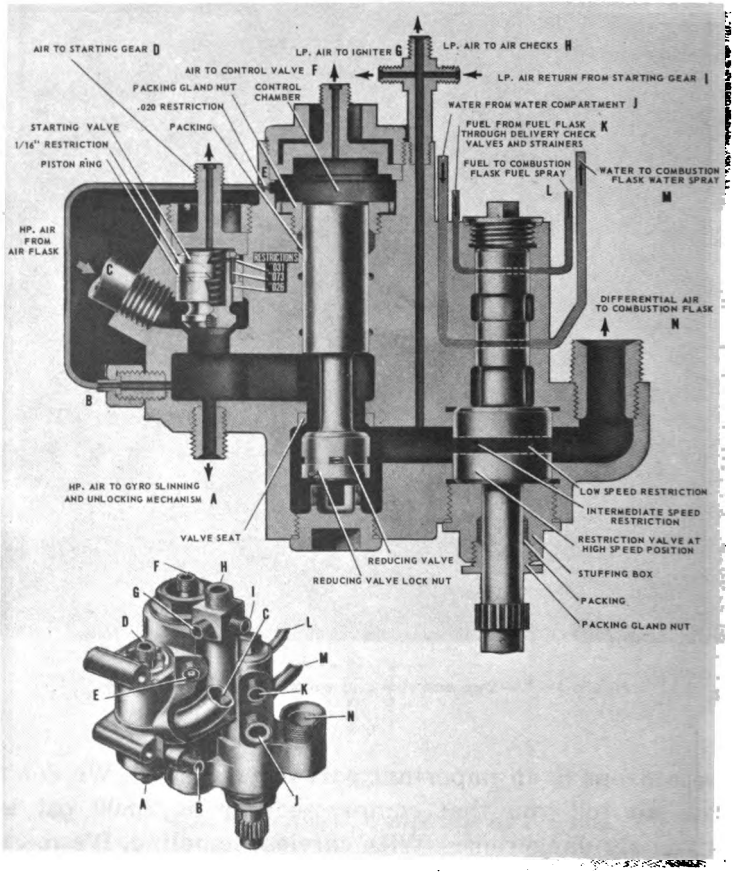

Figure 3–12.—Starting, reducing, and restriction valve group.

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exhaust. Its purpose is to warm up the compressed air before it reaches the reducing valve, to improve the performance of that valve. (The Mk 13 torpedo has no preheater; air goes directly from the stop and charging valve to the starting valve.)

In figure 3–12, find the starting valve, near the left edge of the picture. It's shown in the open position; when there is no air pressure in the line, its spring holds it shut. When you open the stop valve, compressed air reaches the lower face of the starting valve and tends to push it open, against the force of its spring. But, because you open the stop valve slowly, air has time to leak past the starting valve piston and fill the space above it. This air fills the pipe that leads to the starting gear, where it's blocked off. Thus you have flask-pressure air pushing down on the top of the starting-gear piston. This pressure adds to that of the spring, and keeps the valve shut.

When the torpedo is fired, the tripping mechanism in the torpedo tube throws the starting lever aft. That opens the valve in the starting gear, releasing the pressure above the starting-valve piston. Flask-pressure air under the piston then overcomes the spring pressure, and the starting gear opens. (The air that leaks through the starting gear returns to the system on the low-pressure side of the reducing valve.) From the starting valve, flask-pressure air goes to two places: (1) to the gyro spinning and unlocking mechanism, to spin the gyro and quickly bring it up to full speed, and (2) to the reducing valve.

Find the reducing valve in figure 3–12. Flask-pressure air pushes upward on a fairly large area of the reducing-valve piston, and downward on a slightly smaller area. The net result is a slight upward force, tending to keep the valve shut. Flask-pressure air also goes out through the small control pipe at the left of the picture, and enters the control chamber above the reducing-valve piston through a small restriction. The restriction prevents

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any SUDDEN change in pressure in the control chamber. The air that enters the control chamber pushes down on the piston, opening the valve. As soon as air flows through the valve, it will press upward on the bottom of the piston, tending to close the valve.

The valve piston will quickly adjust itself to a position in which the upward and downward forces are exactly balanced. The air that flows through the valve will then be at a pressure considerably below that in the air flask—usually about 450 psi. The actual pressure is determined by the pressure in the control chamber. That, in turn, is determined by the setting of the control valve. Air leaks out of the control chamber through the control valve, and enters through the small restriction. Thus it's easy to keep the pressure in this chamber far below flask pressure.

The reducing valve accomplishes two things. First, it reduces the flask pressure to a suitable working pressure. Second, it assures that the working pressure will remain constant, even when flask pressure drops as the air supply is used up.

Reduced-pressure air goes to three places: (1) to the fuel and water compartments; (2) to the igniter; and (3) into the combustion flask. On its way to the combustion flask, the air passes through a restriction valve, shown at the right in figure 3–12. Fuel and water also pass through passages in this valve. This system ensures that fuel, air, and water will enter the combustion flask at the proper pressures, and in the proper proportions.

In the Mk 15 torpedo, which offers a choice of three speeds, the restriction valve may be turned to bring any of three sets of restrictions into line. The Mk 14, a two-speed torpedo, has a restriction valve with two sets of passages. There is only one set of passages in the Mk 13 torpedo. In the Mk 23, the restriction valve is locked in the high-speed position.

Working-pressure air goes from the reducing valve into the fuel and water compartments, to force fuel and

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water, under pressure, into the combustion flask. Between the reducing valve and the fuel and water compartments are a pair of check valves. These valves are normally closed by spring pressure. They're one-way valves; they keep fuel and water from trickling and sloshing into the reducing valve. When working-pressure air is applied to these valves it quickly forces them open, and passes through them to the fuel and water compartments.

Fuel and water, in flowing from their compartments to the restriction valve, pass through a pair of strainers and a second pair of check valves. The strainers remove any particles of dirt that might clog the passages of the restriction valve. The check valves, normally closed by springs, keep fuel and water from trickling into the combustion flask before the torpedo is fired. But when working pressure is applied to the fuel and water, they easily force the check valves open.

For a quick summary, we'll list all the operations performed by the air system from the time of launching. Before you fire the torpedo, it's loaded in the tube and its stop valve is open. If this is a war shot, the blow valve is closed. There's flask-pressure air in the preheater. There's flask-pressure air on the flask side of the starting valve, and in the line from the starting valve to the starting gear. But air is blocked off at the starting valve and starting gear. There's no pressure in the system beyond those points.

Here's what happens when you fire the torpedo. (Although we'll list the operations in numbered steps, remember this: As soon as the starting valve opens, all the rest of these operations happen almost simultaneously.)

1. As the torpedo begins to move forward in the tube, the tripping latch in the tube strikes the torpedo's starting lever, and throws it aft.

2. The starting gear vents the line from the starting valve, and the pressure in this line drops.

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3. The starting valve opens.

4. Flask-pressure air goes to the gyro-spinning mechanism, which spins the gyro and quickly brings it up to full speed. This mechanism shuts itself off as soon as the gyro reaches full speed. Then no more air goes to the spinning mechanism.

5. Flask-pressure air passes through the reducing valve, which drops it to working pressure—about 450 psi.

6. Air from the starting gear passes back into the system on the low-pressure side of the reducing valve.

7. Working-pressure air flows through the restriction valve, and enters the combustion flask through an air whirl.

8. Working-pressure air opens the air-check valve in the line to the fuel compartment. The pressure in the fuel compartment opens the fuel-check valve, and fuel flows into the combustion flask through a fuel spray.

9. Working-pressure air flows to the igniter and starts it burning. The igniter ignites the fuel-air mixture.

10. Working-pressure air opens the air-check valve in the line to the water compartment. The pressure in the water compartment opens the water-check valve, and water flows into the combustion flask through a pair of water sprays.

11. A mixture of hot compressed air, combustion gases, and steam strikes the turbine blades, and spins the turbines. The turbines, through the gears and shafts of the main engine, spin the propellers.

12. Working-pressure air passes through the air strainer and flows to the depth engine. The depth engine will then operate the depth rudders as soon as it gets an order from the depth-control mechanism.

13. Air from the air strainer body goes to the steering engine. The steering engine will then throw the steering rudders as soon as it gets an order from the gyro.

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14. Air from the air strainer body goes through the gyro reducer, which drops its pressure to about 125 psi. This low-pressure air keeps the gyro spinning.

SUPERHEATING SYSTEM

Compressed air alone could propel the torpedo if necessary, but not as fast or as far as we want. The superheating system, by adding to the volume and speed of the gases that spin the turbines, adds tremendously to the energy of the compressed air. The superheating system consists of the combustion flask, the fuel and water sprays, the nozzle jets, and the igniter. All these parts are on the forward side of the turbine bulkhead. Figure 3–13 is a diagram of the superheating system and turbine wheels of a Mk 14 torpedo.

Air enters the combustion flask through an air whirl, which gives it a spinning motion to mix it with the fuel

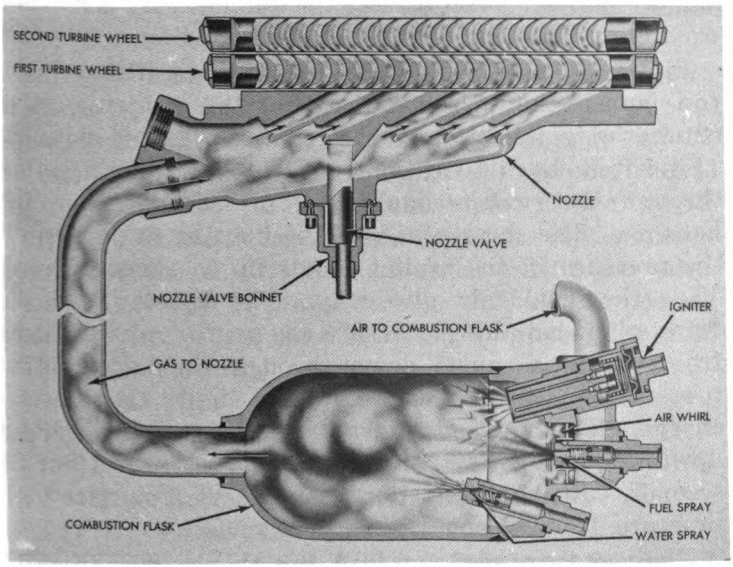

Figure 3–13.—Combustion flask and nozzle unit, diagrammatic view.

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and water. Alcohol is sprayed into the center of the air whirl through the fuel spray. In order for fuel and water to enter the combustion flask, their pressure must be higher than that of the compressed air entering through the air whirl. The restriction valve brings about this condition by reducing the air pressure more than it reduces the pressure of the two liquids.

There are two water sprays; only one of them is shown in figure 3–13. They are longer than the fuel spray, and set farther back in the flask, so that water does not enter the air-alcohol mixture until the mixture has started to burn. The water turns to steam. This serves two purposes. First, it cools the flask to keep excessive heat from destroying it. Second, it adds to the volume of gases that spin the turbines.

Burning of the fuel and air mixture is initiated by the igniter, which screws into a threaded opening in the combustion flask. This opening is ordinarily closed by a dummy igniter. You replace the dummy with a real one when you make the torpedo ready for firing.

Figure 3–14 is a cutaway view of an igniter. When you launch the torpedo, air from the reducing valve enters the igniter through the reduced-pressure air inlet. (Find it in the illustration.) The air pressure, acting through the rubber diaphragm, presses down on the housing. The sheer nibs hold the housing in place until the pressure in the igniter builds up to about 250 psi. Then they suddenly give way. The housing and the firing pins snap down, and fire the primer caps. Flame from the caps spurts down through the two ignition tubes, blows out the end seal, and lights the ignition charge. The ignition charge burns from the bottom upward. In open air, an igniter will burn for 15 or 20 seconds. In the combustion flask, where it's under high pressure, it burns out in about 6 seconds.

The protecting nut and lead disc shown in figure 3–14 serve to keep dirt out of the igniter, and to protect the threads for the air line, when the igniter is being shipped

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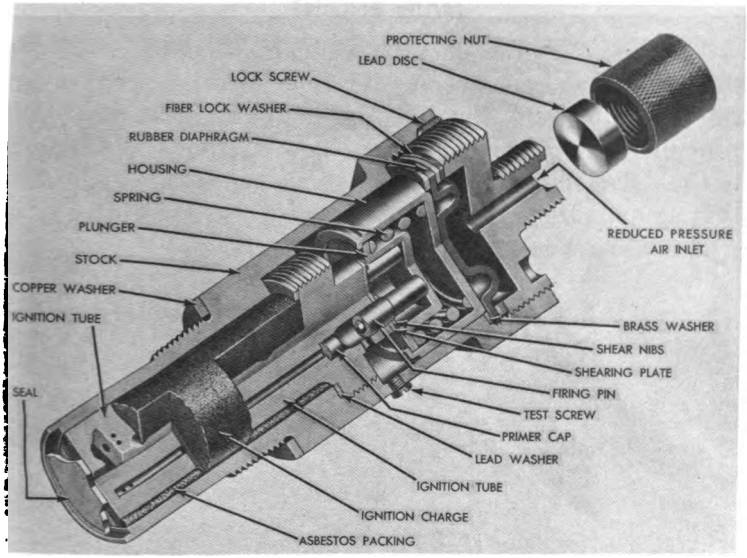

Figure 3–14.—Igniter Mk 6 Mod 4, cutaway view.

or stowed. You remove them before you connect the air line.

The nozzles (fig. 3–13) divide the combustion gases into five separate jets before they strike the turbine blades. The unit shown in the illustration is part of the Mk 14 torpedo. The nozzle valve assembly is part of the speed-change mechanism. In the high-speed setting the valve is down, as shown in the picture, so that all five nozzles are open. In the low-speed setting it's up; only the first two nozzles are open.

The Mk 15 torpedo gives you a choice of three speeds, and its nozzle valve has three different positions:

High speed—all five nozzles open
Intermediate speed—two nozzles open
Low speed—one nozzle open.

The Mk 23 torpedo has only one speed; all five of its nozzles are always open. The Mk 13 has only three nozzles, but they're always open.

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MAIN ENGINE

The main engine of an air-steam torpedo is of the turbine-driven, gear-reduction type. It is made up of the two turbines, the two drive shafts that turn the propellers, the gears that take power from the turbines to the drive shafts, and the spindles, shafts, and bearings that support these parts.

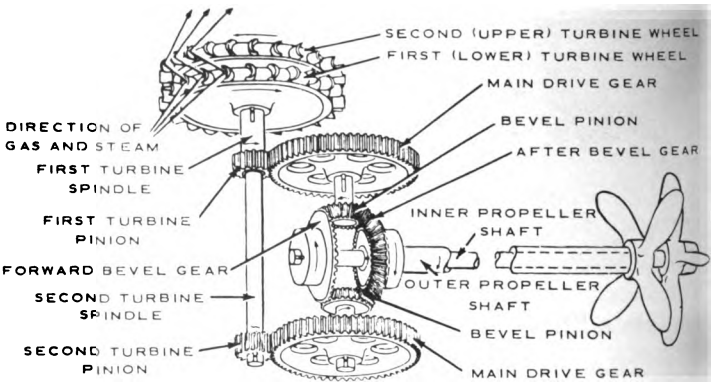

Figure 3–15.—Schematic diagram of the main engine.

Figure 3–15 is a schematic diagram of the main engine. Compare it with figure 3–16, which shows three views of the main engine of a Mk 15 torpedo. The parts we'll mention are not labeled in figure 3–16, but you should be able to find and identify them easily. If you can't, study chapter 9 of *Torpedoman's Mate 3&2, Vol. I,* NavPers 10155, for a review.

An engine of this type is often called a BALANCED engine, because all its rotating parts are in pairs; in each pair, the two parts rotate in opposite directions. A single rotating part, as you know, would set up a gyroscopic force that would interfere with torpedo steering. In the counterrotating pairs, the gyro forces cancel each other. In an air-steam torpedo, the paired

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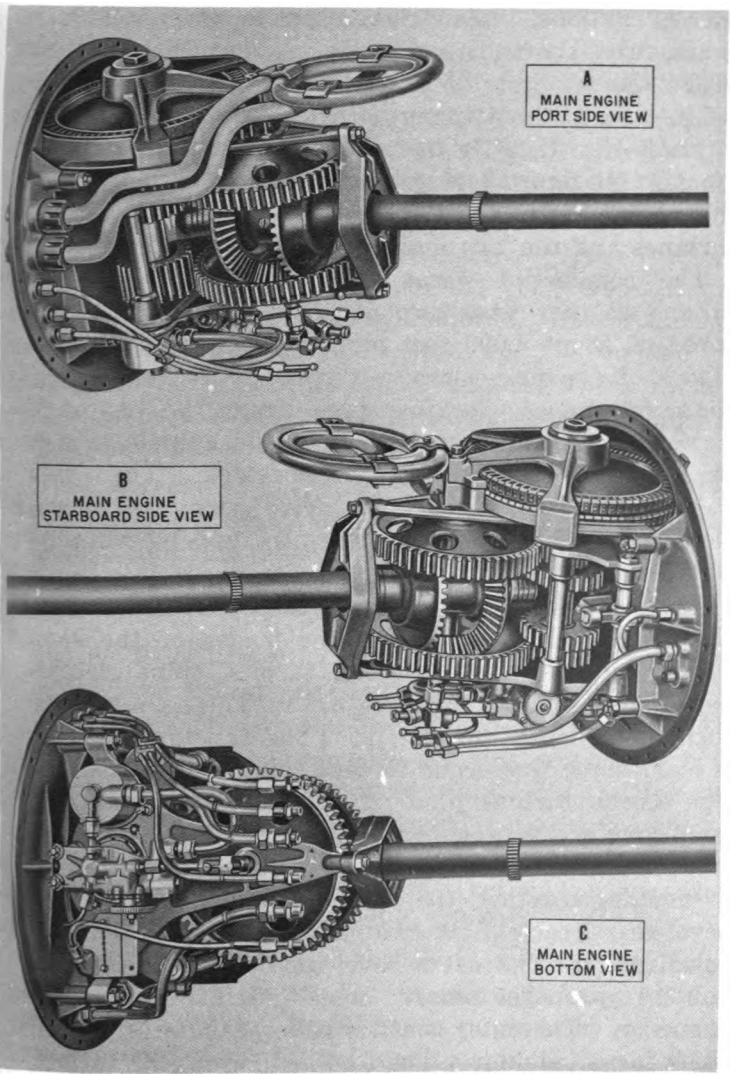

Figure 3–16.—Main engine of a Mk 15 torpedo.

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rotating parts include the turbines, turbine spindles, turbine pinions, main drive gears, bevel pinions, bevel gears, drive shafts, propeller sleeves, propeller hubs, and propellers.

Let's trace the turning force through the engine in figure 3–15. Identify the parts in figure 3–16 as you go along. (In figure 3–15 you're looking at the port side of the engine from a little below the torpedo. The two turbines and the two main drive gears are horizontal.)

The combustion gases from the combustion flask expand as they pass through the nozzles, and reach a speed of about 4,000 feet per second. They strike the blades of the first (lower) turbine wheel, and spin it counterclockwise (looking down from the top of the torpedo). The first turbine turns its spindle, and the first turbine pinion, counterclockwise. The pinion meshes with the upper main drive gear, and turns it clockwise. This drive gear turns the upper bevel pinion in the same direction.

The combustion gases are deflected from the blades of the first turbine, and strike the blades of the second (upper) turbine. The second turbine spins clockwise (still looking down from the top.) The second turbine turns its spindles and pinion. (The first turbine spindle is hollow, and the second turbine spindle turns inside it.) The second turbine pinion turns the lower main drive gear counterclockwise. And the lower main drive gear turns the lower bevel pinion in the same direction.

Working together, the two bevel pinions turn the two bevel gears; each of the two pinions is meshed with BOTH bevel gears. The after bevel gear turns the forward (outer) propeller shaft, which turns the forward propeller. The outer shaft is hollow; the afterpropeller shaft turns inside it. The forward bevel gear turns the afterpropeller (inner) shaft, which turns the afterpropeller.

As you can see, both turbines work together to turn both propellers, at the same speed but in opposite

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directions. We could build a simpler engine by letting the first turbine turn one propeller, and the second turbine turn the other. But then the two turbines and the two propellers would turn at different speeds. (The first turbine delivers about 70 percent of the power; the second delivers only about 30 percent.) Because the two turbines are connected through the gear system, they are forced to turn at the same speed.

Another look at figure 3–16 will refresh your memory on how the main engine is supported. The two A-frames are secured to the turbine bulkhead. The A-frames support the turbine spindle casing, and the turbine top bearing holder. At their after end the A-frames are connected by a strut. This strut carries the bearings in which the forward propeller shaft turns.

The A-frames also support the crosshead. The crosshead itself does not rotate, but it supports the bushings on which the main drive gears and bevel pinions rotate. The afterpropeller shaft passes through an opening in the center of the crosshead.

In the torpedoes Mks 13, 14, and 23, power passes directly from the turbine pinions to the main drive gears, as in figure 3–15. In the Mk 15 torpedo (figure 3–16), the turbine pinions mesh with the side gears, which in turn mesh with the main drive gears. By shifting the side gears you can change the gear ratio of the engine and, therefore, the running speed of the torpedo. If you're a little hazy about the construction and operation of the side gears, review them in OP 642.

During the torpedo run, the main engine is lubricated by an oiling system located in the afterbody. Oil is stored in two tanks. An oil pump, powered by a gear on the lower end of the second turbine spindle, forces oil to the turbine spindle bearings and the crosshead. Oil that leaks through the crosshead bushings is whipped into a spray by the bevel gears; this spray lubricates the gear teeth and propeller shaft bearings. In the Mk 13

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torpedo, the oil pump is of the double piston type; in the others, it is of the gear type.

CONTROL MECHANISMS

The steering and depth mechanisms keep the torpedo on its preset course, at a preset depth. The steering mechanism, controlled by a gyro, operates the vertical rudders to correct any deviation of the torpedo to port or

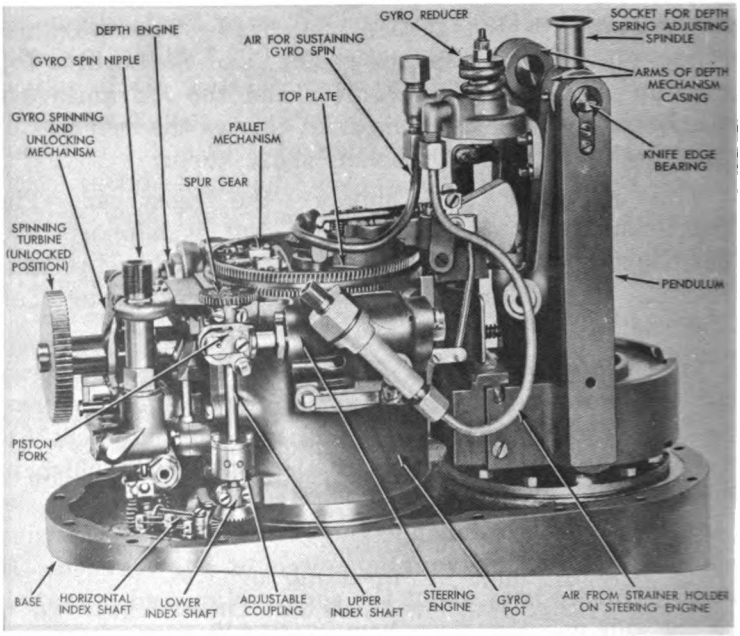

Figure 3–17.—Gyro and depth mechanism, assembled, starboard view.

starboard. The depth mechanism, controlled by a diaphragm and pendulum, operates the horizontal rudders to correct any deviation from the preset depth. The gyro and depth mechanisms are mounted on a single base, shown in figure 3–17.

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Steering Mechanism

The heart of the steering mechanism is the gyro. As you know, a rapidly spinning gyro will resist any force that tends to change the direction of its axis. In the torpedo, the gyro is mounted in an inner gimbal which in turn is mounted in an outer gimbal. This system makes it possible for the torpedo to turn to port or starboard, or up or down, without moving the gyro's axis of spin from its original direction. You'll find a detailed discussion of the gyro and its mounting in chapter 6 of this volume.

The gyro and its gimbals are enclosed in a housing called the gyro pot (fig. 3–17). The gyro pot carries the gyro spinning and unlocking mechanism on its forward side. This mechanism locks the gyro axis in a fixed position parallel to the torpedo center line. In the first fraction of a second after you launch the torpedo, this mechanism brings the gyro up to full speed and unlocks it.

On the upper port and starboard sides of the gyro pot are bosses for mounting the depth and steering engines. On the top plate are the two rectangular bosses that support the pallet mechanism.

The pallet mechanism detects any change in the relative position of the gyro axis, without disturbing the gyro itself. If the gyro position shows that the torpedo has turned off its preset course, the pallet mechanism sends appropriate orders to the steering engine. Figure 3–18 shows the pallet mechanism and its linkage to the steering engine valve.

The cam plate (find it in figure 3–18) is mounted on the outer gimbal of the gyro. If the torpedo turns with respect to the gyro, it must also turn with respect to the cam plate. The cam on the edge of the plate is in line with the gyro axis.

The driving spindle is powered by a gear on the torpedo's outer propeller shaft. Through a pair of bevel

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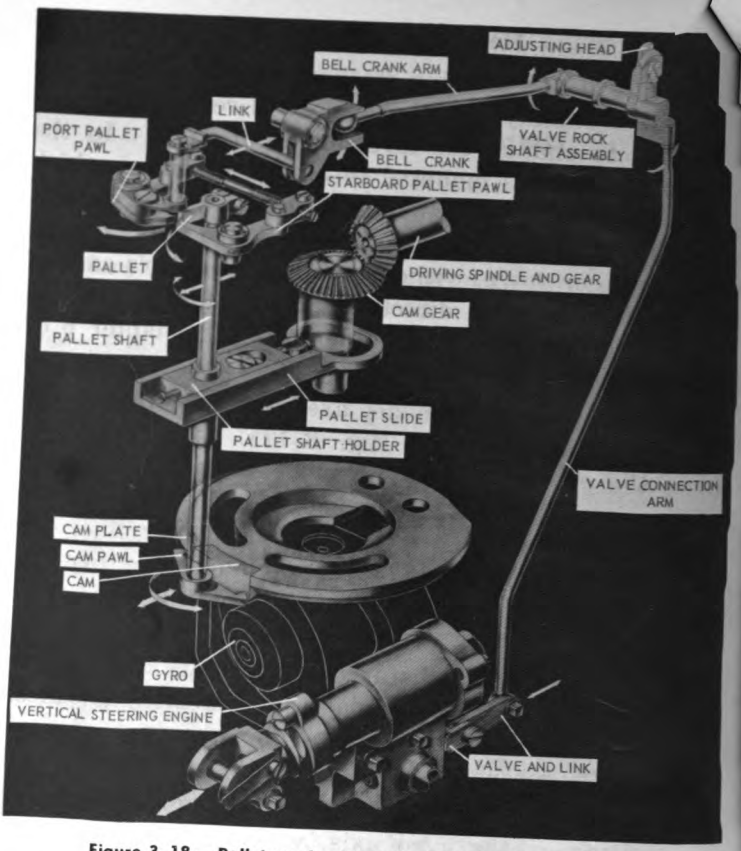

Figure 3–18.—Pallet mechanism with linkage to steering engine.

gears, the spindle turns the driving cam, which in turn gives the pallet slide a back-and-forth motion. The vertical pallet shaft is free to turn within its holder, but it must move back and forth with the pallet slide. If the torpedo is exactly on course, the two cam pawls will straddle the cam. If the torpedo is off its course, one of the cam pawls will strike the cam and turn the pallet shaft in its holder. Then, as the shaft moves away from the cam plate, the pallet blade will strike one of the pallet

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pawls, and thus send a steering order through the linkage to the steering engine valve. The two pallet pawls are linked together so that when one of them is pushed aft, the other moves forward.

Let's say that the torpedo turns off its course to port. The gyro axis and the cam plate are still parallel to the course; the torpedo axis is pointing left of the gyro axis. Since the pallet shaft is abaft the cam plate, it has moved to the starboard side of the cam. Here's what happens:

1. When the pallet slide moves forward, the port cam pawl strikes the cam.

2. The pallet shaft turns counterclockwise (looking down from the top).

3. The pallet blade swings to starboard.

4. When the pallet slide moves aft, the pallet blade strikes the tip of the starboard pallet pawl.

5. The tip of the starboard pallet pawl moves aft, forcing the tip of the port pallet pawl forward.

6. Through the linkage shown in figure 3–18, the pallet pawls push the steering engine valve aft.

7. The steering engine piston moves forward, pulling the steering rudder rod with it.

8. Through its yoke, the rudder rod applies right rudder.

9. The torpedo turns to starboard, back toward its course.

But the torpedo doesn't stop turning when it comes back on course. It swings off course on the other side. When the steering engine gets an order, it throws the rudder hard over. The rudder stays there until the engine gets the opposite order. And of course, there will be no new order to the engine until the torpedo has crossed its course, so that the other cam pawl can strike the cam.

So the track of a torpedo isn't a straight line. The rudder oscillates constantly, and the torpedo weaves back and forth across its course. But because the pallet

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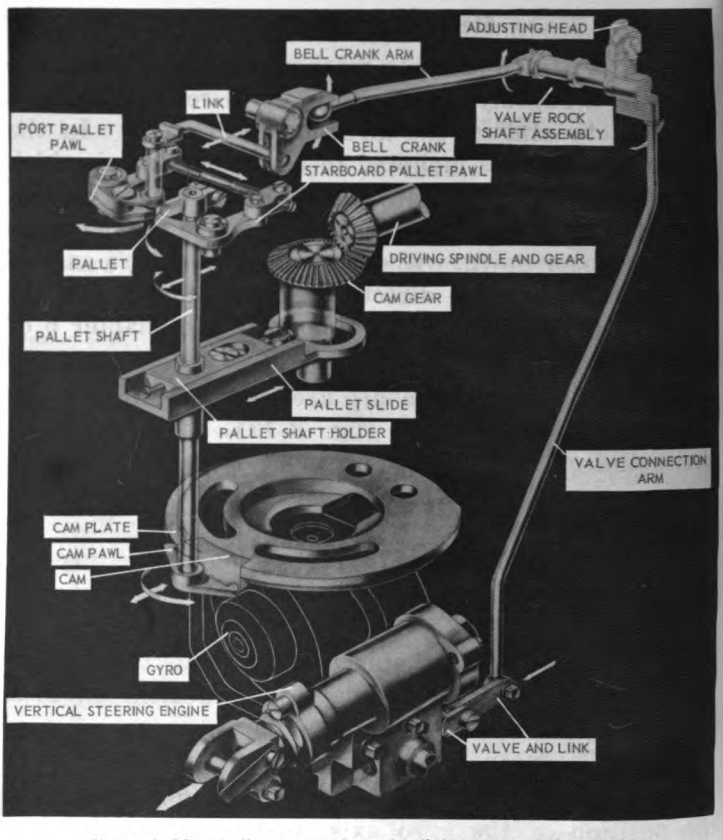

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So the track of a torpedo isn't a straight line. The rudder oscillates constantly, and the torpedo weaves back and forth across its course. But because the pallet

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mechanism is sensitive, the weaving is small; the actual track is very close to a straight line.

Depth Mechanism

While the steering engine brings the torpedo onto its proper course and keeps it there, the depth mechanism brings it to its proper depth and keeps it there. The two horizontal depth rudders control the running depth of the torpedo. The depth engine, powered by compressed air from the reducing valve, operates the rudders. And the depth mechanism sends orders to the valve of the depth engine.

The principal parts of the depth mechanism are a hydrostatic diaphragm and a pendulum. These two parts work together to send orders to the depth engine. There are two reasons why the depth engine may need new orders. First, the torpedo may be running at the wrong depth. Second, it may be changing its depth at too steep an angle.

Let's say that the torpedo is running below the depth you set it for. The diaphragm responds to the extra water pressure, and sends an UP RUDDER order to the depth engine. The torpedo begins to climb. If the engine gets no further orders, the torpedo will be climbing fast when it reaches the right depth, and it will overshoot. Then the diaphragm will send a DOWN RUDDER order. The torpedo will go down and overshoot again. So, if the torpedo is going to make a successful run, the depth mechanism must control not only its depth but also the rate at which it changes depth.

Figure 3–19 shows how the diaphragm and pendulum work together.

Under the diaphragm is a sealed chamber of air. Sea water reaches the upper surface of the diaphragm through passages provided for it, and tends to push the diaphragm down. The spring, since it's under tension, resists this downward force. (By adjusting the tension

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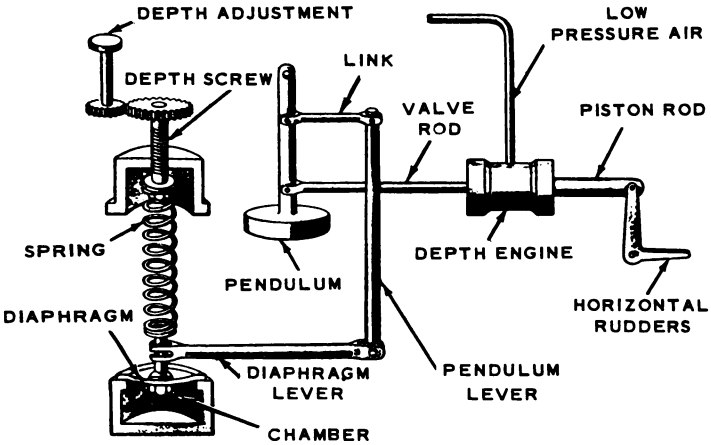

Figure 3–19.—Schematic diagram of the depth mechanism.

on this spring, you can set the depth at which the torpedo will run.)

Now to see how the mechanism works, let's say that the torpedo is running below the set depth, with its axis horizontal. Water pressure pushes the diaphragm down, against the force of the spring and the resistance of the air trapped in the chamber. The downward movement of the diaphragm rocks the diaphragm lever counterclockwise. Since the diaphragm has only a limited movement, the lever is pivoted near the diaphragm so that it multiplies the diaphragm movement by a factor of 18.

The pendulum lever and link transfer the rocking movement to the pendulum, swinging it forward. (That's to the left in the diagram.) The pendulum pulls the depth engine valve rod forward. The depth engine is built so that its piston follows the movement of the valve. So the piston moves forward, applying up rudder, and the torpedo begins to climb.

But as the torpedo turns upward, gravity tends to pull the pendulum aft (to the right in the diagram), against the action of the diaphragm. That reduces the amount

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of up rudder. When the climbing angle is just steep enough to make the diaphragm action balance the pendulum action, the rudder will be in neutral. But the torpedo will still be climbing.

As it climbs, the water pressure becomes less. So the downward pressure on the diaphragm decreases. That lets the pendulum move farther to the right, and apply down rudder. So the torpedo begins to level off. It reaches its set depth at a slow rate of climb. In that way the pendulum tends to prevent overshooting. And the torpedo runs at a nearly uniform depth—the depth you've set by adjusting the tension on the diaphragm spring.

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QUIZ

1. Give two reasons why now might be a good time for you to review the construction and operation of the air-steam torpedo.
2. If you need a more thorough review than you find in this chapter, where can you get it?
3. Torpedo-propelling mechanisms are of two basic types. What are they?
4. Name the four marks of air-steam torpedoes discussed in this chapter.
5. Which of these is an aircraft torpedo?
6. Which mark of torpedo has two speeds? Three speeds?
7. What is the difference between the Mk 14 and Mk 23 torpedoes?
8. What mark of torpedo uses the navol cycle? What is navol?
9. Name as many advantages of navol torpedoes as you can think of.
10. Which two sections of the torpedo are permanently joined? Which two are shipped as a single assembly?
11. The head section may be any of three kinds. Name them.
12. Name three devices that might help you to find a torpedo after an exercise run.
13. Why is the explosive cast on a slant in some torpedo war heads?
14. Name two important functions of the torpedo exploder.
15. Why are war heads made of phosphor bronze, rather than steel?
16. What is the function of the air-releasing mechanism?
17. What is the function of the water discharge valve?
18. Where is the blow valve? What does it do? For a war shot, is it open or closed?
19. How can you reach the inside of the air flask if you need to clean it?
20. Where are the water compartment and fuel flask located?
21. Name six valves mounted on the shell of the midship section.
22. Why do we permit sea water to enter the midship section during the torpedo run?

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23. Name THREE mechanisms that make it possible to change the speed of a Mk 15 torpedo. Which of these is NOT present in the Mk 14?

24. What is the purpose of the air whirl?

25. What is the function of the vertical rudders? The horizontal rudders?

26. Where do the exhaust gases go after they pass through the valves in the afterbody bulkhead?

27. What is the pressure in the air flask when it's fully charged?

28. At approximately what pressure is air used for the following: igniter; gyro-spinning mechanism; gyro sustaining air; depth and steering engines?

29. What mechanism makes it possible to introduce air into the combustion flask at a pressure lower than that of the fuel and water?

30. How does the starting gear start the torpedo?

31. What does the control valve do?

32. What is the purpose of the preheater? Where is it located?

33. What is the purpose of the four check valves?

34. What is the purpose of the fuel and water strainers?

35. Name the paired, counterrotating parts of an air-steam torpedo.

36. What is the function of the A-frames?

37. How are the gear teeth of the main engine lubricated during the torpedo run?

38. Which torpedo has a double-piston type oil pump? What kind of oil pump do the others use? What drives the oil pump?

39. What is the function of the pallet mechanism? What provides the power to operate it?

40. What is the purpose of the pendulum in the depth mechanism?

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CHAPTER 4

REVIEW OF FIRING AND RECOVERY

In this chapter we will briefly review the procedures for firing torpedoes from above-water trainable tube mounts, and from the submerged tubes of submarines. And we will summarize the procedure for the recovery of exercise torpedoes. (Firing from special launchers, and from above-water fixed tubes, will be discussed in volume 2 of this course.)

Why do you need a review? You have probably served in one or more positions in the torpedo crew of a destroyer or submarine—possibly in both. And you have probably served as a member of the torpedo recovery crew. But as a Torpedoman's Mate 1 or C, you may have to take charge of the torpedo battery during firing. You must be prepared to fire either by local control or by director control. On a destroyer, you will probably act as torpedo mount captain, taking a station at or near the tube mount, and supervising the work of each member of the firing crew. Figure 4–1 shows the torpedo officer at his station, supervising the operation of the torpedo director; in an emergency, you may have to take his place.

In order to supervise operation of the torpedo battery you must be able, if necessary, to perform the duties of each member of the crew. And you must have a thorough understanding of the firing procedure as a whole. This

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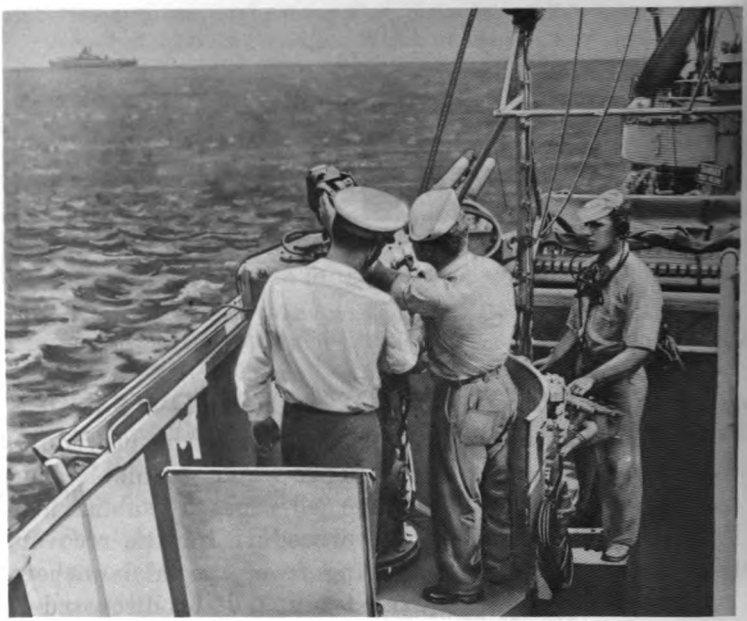

Figure 4–1.—Torpedo officer supervising director operation during practice drill.

chapter names the members of typical torpedo crews of destroyers and submarines, outlines their usual duties, and describes the usual firing procedures. But remember, as you read, that firing procedures on your ship may differ somewhat from those given here. The exact procedure will depend on the wishes of the commanding officer, and on current fleet doctrine.

ABOVE-WATER TRAINABLE TUBES

The following outline will give you a quick, overall view of the makeup of a typical destroyer's torpedo crew; it very briefly summarizes the duties of crew members, and of the captain and torpedo officer, during torpedo action.

CAPTAIN. Stationed on the bridge. Designates the target, and the method of fire to be used. Conns the

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ship to bring the torpedo battery into a suitable position for firing.

TORPEDO OFFICER. Stationed near the torpedo director. Responsible for overall supervision of the torpedo battery. Makes the necessary inputs to the torpedo director, using information supplied by the captain, by CIC, or based on his own estimates. When more than one ship is firing, he makes the setup ordered by the division commander, and fires as directed. In the event of casualty to any of the automatic inputs of the director, he makes the necessary inputs by hand.

TORPEDO DIRECTOR OPERATOR. Stationed near the torpedo officer. Relays information and orders from the torpedo officer to the tube mount. Operate selector firing switches.

DIRECTOR TRAINER. Stationed at the torpedo director. Keeps the director trained on the target, and operates the director firing key.

TORPEDO MOUNT CAPTAIN. Stationed at the tube mount, and directly supervises personnel at the mount. Sees that orders are properly carried out. Handles any casualties that may occur. Estimates target speed, range, and target angle, for emergency use.

MOUNT TRAINER. Stationed at the tube mount. Trains the mount to keep the zero readers of the torpedo-course dial matched, or as ordered.

GYRO SETTER. Stationed at the tube mount. Sets gyro angles, either by keeping zero readers of the gyro-angle dial matched, or as ordered. May assist the battery captain in making the torpedo depth setting.

(NOTE: On older destroyers, equipped with two tube mounts, the crew usually included a battery captain responsible for the operation of both mounts, and a mount captain at each mount. On present destroyers equipped with a single tube mount, these duties are likely to be combined.)

Torpedo Officer

The torpedo officer is responsible to the commanding officer for the efficient operation of the torpedo battery

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and the torpedo-control system. When the commanding officer designates a target, the usual duties of the torpedo officer include the following:

1. Orders "Torpedo action port (starboard)." Designates the target and its approximate bearing to the director trainer and the mount captain.

2. Orders the type of firing to be used (bridge control or local control.) If bridge control, orders "Match pointers."

3. Orders torpedo depth setting, in feet.

4. Informs the director trainer and tube personnel of the number of torpedoes to be fired, the spread angle, and the torpedo speed setting.

5. Informs the director trainer of target course and speed.

6. Informs tube personnel of target angle and speed.

7. Checks tube train and gyro angle to ensure firing on a safe bearing. Orders readjustment of the director setup if necessary.

8. Checks to make sure the target is within effective torpedo range.

9. Reports "On target" to commanding officer. When directed by the commanding officer, orders "Stand by," then "Fire one, Fire two," and so on.

Torpedo Mount Captain

The torpedo mount captain is usually a Torpedoman's Mate Chief. He is stationed at the tube mount, unless otherwise ordered. His primary duties are to prepare the tube for firing, and to supervise the tube trainer and gyro setter in operation of the mount. He is under the immediate supervision of the torpedo officer, and is responsible to the torpedo officer for the efficient performance of all personnel assigned to the torpedo crew.

At general quarters, the torpedo battery captain checks to see that all stations at the tube mount are manned. If a station is not manned he assigns another member of

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the crew to that station, or, if necessary, takes over its duties himself. He supervises all members of the torpedo crew, making sure that each job is done right, and that all safety precautions are observed. He stands by to correct any material casualties.

The mount captain should estimate target angle, target speed, and range, independently of the information received from CIC. If necessary, he can give his estimates to the tube trainer, who can set up the problem on the tube sight. Thus, if any casualty should occur to the director, local control could be used immediately.

In preparing the mount for firing, the mount captain must personally see that the tripping latches are down in the firing position, and that the torpedo guide-stud stops in the stop mechanisms are secure. He must closely watch and supervise the work of the tube trainer and gyro setter, and correct or advise them if necessary. The tube mount captain personally cocks the firing mechanism of each barrel, inserts primers in the impulse charges, and loads them as necessary. He changes the torpedo speed setting when ordered to do so. Figure 4–2 shows the mount captain making a speed change.

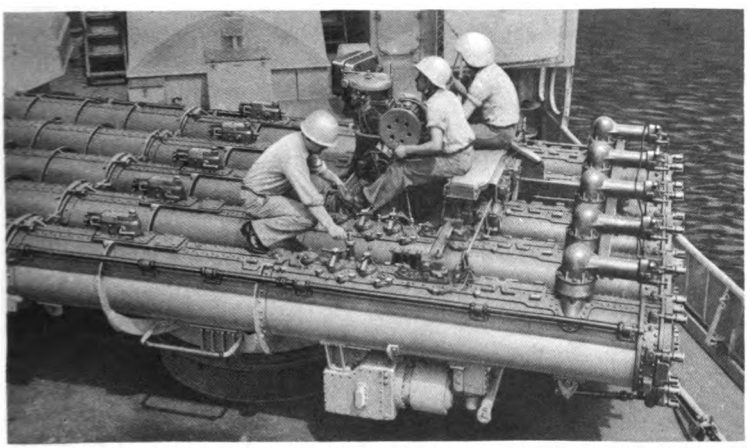

Figure 4–2.—Tube mount captain making a speed change during a drill.

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As tube mount captain, you must develop a high degree of skill in preparing the tube mount quickly, and in making accurate estimates for use in local control. If communications fail during battle, your estimates will be the only ready source of the necessary information.

Tube Mount Trainer

In figure 4–2, the mount trainer and gyro setter may be seen at their stations atop the mount. The tube trainer helps the mount captain to prepare the tube for firing. During firing, he trains the tube, keeping the torpedo-course pointers matched on the torpedo-course indicator dial. He usually wears phones, and relays messages from the torpedo officer to the gyro setter and mount captain. After firing, the tube trainer reports the expenditures and casualties, if any, to the torpedo officer. When requested to do so, he reports the base torpedo course, gyro angle, and tube train readings as shown on the tube indicating dials.

The tube trainer must be highly skilled in matching pointers on the torpedo-course indicating dial. He must thoroughly understand the procedure for tracking a target in local control, using an open sight of the Mk 5 type. (Instructions for use of the Mk 5 sight are given in *Torpedoman's Mate 3&2*, Volume 2, NavPers 10156.)

Gyro Setter

The gyro setter helps the mount captain and tube trainer in preparing the mount for firing. He makes any necessary changes in the torpedo settings when ordered to do so by the mount captain. He keeps a close watch on the tube-train indicator dial, and warns the tube trainer when he is about to train the mount onto a danger bearing.

Torpedo-Director Operator

The director operator is usually a Torpedoman's Mate second class. He assists the torpedo officer in making

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manual inputs to the director, including target range, target course, target speed, and target bearing, as this information is received by phone from CIC. When this information is not available from CIC, the director operator may assist the torpedo officer in making visual estimates of target speed, target angle, and target course.

At general quarters, the director operator wears phones, and relays the orders of the torpedo officer to personnel at the tube mount. Since the battle station of

Figure 4–3.—Operating the firing-selector switches during a drill.

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the torpedo officer is at the director, he can not give personal supervision to the tube mount personnel. This makes it important that his orders be transmitted quickly, clearly, and word-for-word. The director operator must therefore have good hearing and good enunciation, and he must be thoroughly familiar with the standard orders and terms used in torpedo and depth-charge batteries.

During actual firing, the director operator operates the torpedo-firing selector switches. He must therefore know the several types of torpedo attacks (as set forth in current doctrine) and the number and sequence of the torpedo-firing selector switches applicable to each type of firing. He must develop skill in closing the proper torpedo-firing selector switches while simultaneously transmitting the proper firing orders to the torpedo tube mount. (See fig. 4–3.)

Torpedo-Director Trainer

The director trainer is usually a Torpedoman's Mate third class. His primary duty is to train the director, keeping the telescopic sight on the designated target or on successive points of aim. When control data are received from CIC, and set into the director by the torpedo officer and director operator, the director trainer keeps the director trained by matching the pointers on the bearing indicator. Figure 4–4 shows the director trainer at his station.

Firing from AW Trainable Tubes

This section is intended only to give you a general idea of what takes place during torpedo fire from a destroyer with a trainable quintuple tube mount. For the latest firing doctrine and step-by-step firing procedure, we suggest that you consult the destroyer tactical bulletin (DTB) *Destroyer Torpedo Doctrine and Manual of Torpedo Control.*

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Figure 4–4.—The torpedo-director trainer at his station.

The procedure for a war shot is the same as that for an exercise shot, with one or two exceptions. Since you don't intend to hit the target with an exercise torpedo, you adjust the depth setting so that the torpedo will pass under the target, rather than smash into it. You aren't interested in getting your torpedo back after a war shot, but you do want to recover an exercise torpedo. (We will discuss torpedo recovery later in this chapter.)

When the general quarters alarm is sounded, the torpedo crew mans the torpedo battery as quickly as possible. The first steps are to uncover the torpedo director and the tube mount, including its open sight. All life lines and ship's equipage are cleared from the probable path of the torpedoes to be fired. The director operator and

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tube trainer put on their battle phones and test communications between the two stations. They then report their state of readiness to the torpedo officer.

The torpedo-director operator turns the director power switch clockwise to the ON position, and makes as many inputs into the torpedo director as possible, including torpedo speed, target speed, and target course. The torpedo mount captain orders the tube trainer to unlock the hand clamp on the tube training gear, and to train the tube mount out to a safe bearing. (It will then be possible to fire a torpedo from the tube by using gyro angle, even if the training gear of the tube mount is damaged before the problem is set up and the mount trained to the proper bearing.)

The torpedo officer has asked all stations to report when manned and ready. When they have done so, the torpedo officer reports to the commanding officer that the battery is manned and ready.

When the commanding officer designates a target, the torpedo officer will order the torpedo-director trainer to start tracking the target in the director sight. He trains the director on the target by looking through the telescope and turning the training handwheels until the cross-lines bear on the target. (Or, he trains the director by turning the handwheels to match the dials of the bearing receiver.)

The director operator notifies the tube trainer that he is to match the pointers of the torpedo-course indicator dial, and keep them matched until further orders. The tube trainer notifies the mount captain of the order received, and complies with the order under the supervision of the mount captain. He unlocks the hand clamp on the tube mount training gear, turns on the electric-hydraulic training-gear motor, and trains the mount until the pointers of the torpedo-course indicator dial are matched. Figure 4–5 shows the Torpedo-Course Indicator Mk 1 Mod 4.

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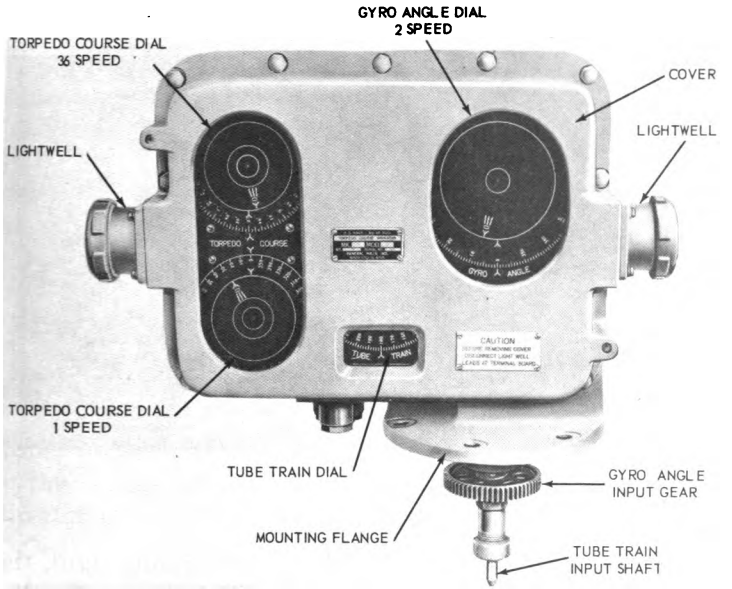

Figure 4–5.—Front view of Torpedo-Course Indicator Mk 1 Mod 4.

On orders from the bridge, the tube mount captain loads impulse charges into the impulse housings (fig. 4–6) and cocks the firing hammers. He should load impulse charges only into the firing chambers of the barrels to be fired. If he should load all the firing chambers, more torpedoes than expected might be fired if the torpedo-director operator should accidentally close the wrong firing-selector switch at the bridge control panel.

The gyro setter stands by for any necessary changes in gyro angle, torpedo speed, and depth setting. When the torpedo officer has the correct setup, he orders spindles disengaged. If the tube is now ready to fire, the tube trainer turns the ready light to its ON position, lighting the mount ready light and the mount ready and indicating light on the bridge. (If, because of a casualty,

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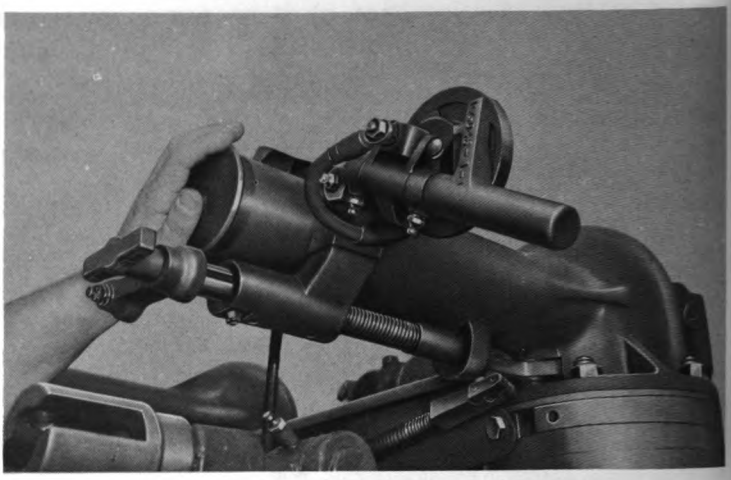

Figure 4–6.—Loading an impulse charge.

the tube trainer later turns off his tube ready light, the ready light at the director panel will also go off. The torpedo officer will then order check fire until the tube is ready.)

When the torpedo officer is almost ready to fire a torpedo, he orders STAND BY. When this order is received, the gyro setter will check to see that all the spindles are withdrawn from the torpedoes. The tube captain will make sure that the tripping latch handles are in their proper positions, so that the tripping latches will engage the starting lever of each torpedo as it leaves the tube.

The torpedo-director operator will turn on the selector firing switch, and the torpedo-director trainer needs only to close the firing key mounted on top of the director to fire the torpedo from the barrel of the tube mount. As the torpedo officer gives the order to fire the torpedoes, the talkers will repeat the order so that the mount captain can fire the torpedo by percussion should the electrical firing circuit fail.

NOTE. The barrels of an above-water tube mount are numbered from right to left. Thus when the mount is trained to starboard,

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the No. 1 barrel is aft and the No. 5 barrel is forward. The normal firing order for a salvo is from aft to forward. Therefore, when firing is to starboard, and the torpedo officer (at the starboard torpedo director) orders "Fire one," the torpedo control talker operates the No. 1 selector firing switch. But when the mount is trained to port, the No. 5 barrel is aft and the No. 1 barrel is forward. When the torpedo officer (now at the port director) orders "Fire one," the torpedo control talker operates the No. 1 selector switch on the port panel; but the wiring is so arranged that the No. 5 barrel is fired. The No. 2 selector switch on the port panel controls the No. 4 barrel, and so on.

Standard Torpedo Battery Orders

This section lists some of the most important standard orders and reports used in torpedo fire. The torpedo-director operator relays all orders given to him by the torpedo officer, and the tube mount trainer relays reports to the bridge. In telephone conversation, the torpedo-director operator is addressed as "torpedo control."

Order.—"All stations report when manned and ready."

From.—Torpedo officer.

To.—All stations.

Action.—Petty officers in charge of each station check to see that all men under their supervision are present. They report to the torpedo officer via "torpedo control" that the stations are manned and ready. If stations are manned but not ready, they so report.

Report.—"Tube mount is manned and ready."

From.—Mount captain.

To.—Torpedo control.

Action.—Torpedo-director operator informs the torpedo officer that the tube mount is manned and ready, and relays any other information that he may receive.

Order.—"Prepare tube for firing."

From.—Torpedo officer.

To.—Tube mount.

Action.—Mount captain supervises preparation of the tube mount for firing. (He has already lowered the life-line stanchions, uncovered the Mk 5 torpedo tube sight,

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and has checked to see that the tripping latches are down.)

Order.—"Commence tracking surface target: bearing 135°."

From.—Torpedo officer.

To.—Tube mount.

Action.—On receiving this order from torpedo control, the mount captain orders the tube trainer to train out the tube mount and begin tracking the assigned target. The trainer continues tracking until otherwise ordered.

Order.—"Turn ready lights on."

From.—Torpedo officer.

To.—Tube mount.

Action.—Torpedo control relays the order, and waits for the tube trainer to report that he has turned on the ready-light switch at the torpedo-tube mount. The director operator then reports to the torpedo officer that the ready lights are on. (The mount captain has already loaded the impulse charges, cocked the firing mechanisms, and assisted the gyro setter in disengaging the spindles.) The mount captain makes a final check to be sure that personnel and ship's equipage are not in the probable path of the torpedoes to be fired.

Order.—"Stand by to fire."

From.—Torpedo officer.

To.—Tube mount.

Action.—As soon as the mount captain acknowledges this order, he readies himself near the breech of the firing mechanism with a rawhide maul or mallet, so that he can fire the torpedo by percussion if the electric circuit should fail. The director operator turns the selector firing switch "ON." This indicates, at the tube mount, the barrel to be fired. The director operator stands by to close the firing key when ordered to do so.

Order.—"Fire one."

From.—Torpedo officer.

To.—Director trainer.

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Action.—The director operator repeats this order over the phone circuit as the director trainer closes the firing key. The tube mount trainer also repeats the order, so that the mount captain can strike the firing pin of the firing mechanism with the maul.

Order.—"Cease firing."

From.—Torpedo officer.

To.—All stations.

Action.—The director operator turns off the power to the director, but makes no other changes in the director setup. If exercise shots were fired, the mount captain unloads any live impulse charges and orders the tube trainer to train the mount to 000° (unless otherwise ordered by the commanding officer). When war shots are fired, the tube mount is normally kept trained out so that firing can be resumed quickly if necessary.

FIRING FROM SUBMERGED TUBES

The duties of the crews in the forward and after torpedo rooms of a submarine are essentially the same. Most of the following discussion will apply equally well to either of the two torpedo rooms. The forward torpedo room is usually in the charge of a Chief Torpedoman's Mate (who may also be chief of the boat), and the after room is usually supervised by a Torpedoman's Mate first class. Or, on some boats, both rooms may be supervised by first class rates.

Torpedo Tube Captain

In each torpedo room, the torpedo tube captain supervises the loading and firing of the tubes. He performs many of the critical tasks himself, such as operating the torpedo tube's blow-and-vent manifold.

During actual firing, he stations himself centrally at the breech end of the torpedo tubes, and supervises the crew in carrying out the adopted firing procedure. He makes necessary mechanical adjustments in preparing

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the torpedoes for firing, and reports the torpedo room manned and ready.

The tube captain readies the loaded torpedo tubes for firing by flooding them with water from the W.R.T. (water round torpedo) tank, building up the pressure to within 5 pounds of sea pressure. Figure 4–7 shows a tube being flooded.

The tube captain opens the outer doors hydraulically. (The outer door mechanism is described in *Torpedoman's Mate 3 & 2*, Volume 2.) On the order to "Stand by," he cocks the poppet valve by hand and awaits the firing order from the conning tower.

From 3 to 5 seconds after each tube has been fired, the tube captain opens the tube vent valve (which automatically closes the poppet valve) and then closes the tube vent when the tube has filled with water. After firing, he readies the tube for reloading by closing the muzzle doors and slightly opening the tube blow valves

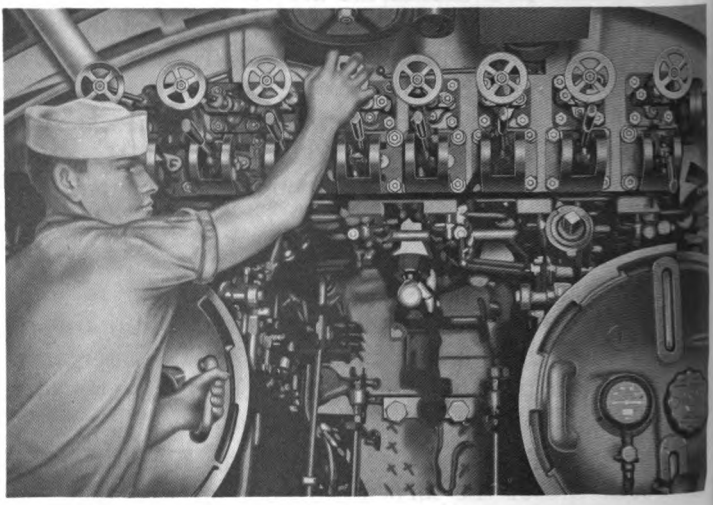

Figure 4–7.—Flooding the tube from the W.R.T. tank.

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to force the water from the tubes and into the W.R.T. tank. When the tubes are empty, the tube captain will secure the tube blow valve, open the tube vents, open the breech doors, and check the barrel interiors to see that the stop bolt is down, the tripping latch up, and that all spindles are retracted.

The tube captain also supervises loading of the torpedo tubes, the removal of propeller locks, removal of starting-gear safety devices, and tightening of the tail stop after the breech is closed on a loaded tube. He supervises the gyro setter, drain valve operators, the man between the tubes, and the reload crew, receiving reports from their stations and visually checking their performance. He may also record torpedo angles in the torpedo record log.

The tube captain must be skilled in supervising his assistants while doing his own work. He must also be skilled in detecting material casualties in torpedoes and tubes, and in making emergency repairs.

Drain Valve Operator

The drain valve operator is usually a Torpedoman's Mate second class or third class. He receives close to moderate supervision from the tube captain. His duty station is at the rear of either the starboard or port tube assembly, near the drain-valve manifold that he operates.

When the order to ready the tubes for firing is given, the drain valve operator opens the drain valves of the W.R.T. tank, allowing the tube to flood until the pressure builds up to within 5 pounds of sea pressure. He then closes the drain valves. If the poppet valve does not close properly after the torpedo is fired, the drain valve operator is responsible for closing the emergency stop valve.

After the tube has been fired, the drain valve operator opens the tube drain valve, so that the water in the tube can drain into the W.R.T. tank. During the reloading

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Figure 4–8.—Filling the firing valve through the filling funnel.

procedure, he fills the torpedo firing valves with clean fresh water. See figure 4–8.

The starboard drain valve operator checks the impulse air gages for proper pressure. When the blow-and-vent manifold is split, he may operate the one that the tube captain is unable to reach.

The drain valve operator must have a thorough understanding of torpedo-tube construction and operation, especially the function of the drains, valves, and vents he is responsible for. He must be skilled in operating the drain valves, in detecting troubles, and in improvising minor repairs.

Gyro Setter

The gyro setter is usually a Torpedoman's Mate second or third class. He receives supervision from the torpedo tube captain. His station is at the gyro-setting indicator-regulator between the torpedo tubes (fig. 4–9).

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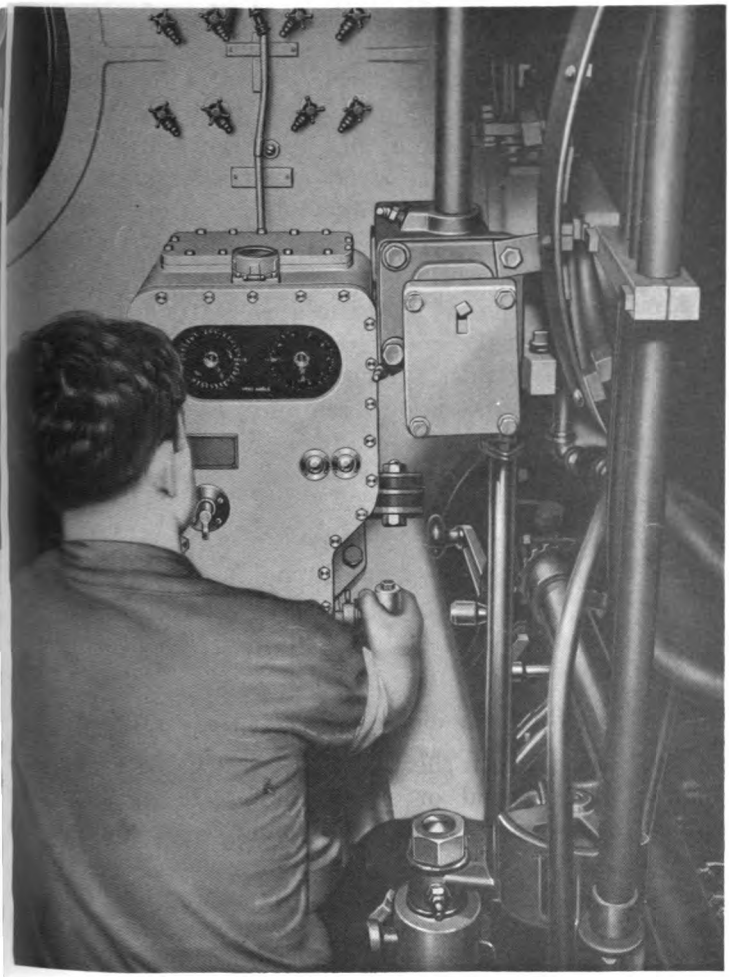

Figure 4–9.—Operator at gyro-setting indicator-regulator.

He observes the gyro angle sent down by the torpedo data computer, together with the torpedo gyro settings, to be sure they are properly matched in automatic control. He must correct any discrepancies in the dial readings by using the hand setting gear.

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On hearing the order to make ready the tubes, the gyro setter checks to see that the gyro-setting mechanism is working correctly in automatic control. He operates a lever to inform the conning tower that the equipment is working properly, and that the gyro settings on the tubes are matching the gyro angle introduced by the TDC. Should the gyro settings not match, he notifies the conning tower, then switches the gear to hand operation and matches the readings manually.

As each torpedo is fired, the gyro setter reports over the phone circuit the gyro setting indicated at the instant of firing. His report permits the firing officer to make any necessary gyro-angle correction. During the reloading procedure, the gyro-setting mechanism is turned off with the setting at gyro-angle zero for forward tubes, and 180° for after tubes.

The gyro setter must be skilled in matching the gyro-setting indicator dials and in making correct reports quickly over the phone. He should have a thorough knowledge of the use and principles of the gyro-setting mechanism.

Man Between the Tubes

The man between the tubes is also usually a Torpedoman's Mate second or third class. He operates the interlock levers and the hand firing keys, making his station between the tube assemblies near these units. (See fig. 4–10.) In preparing the tubes for firing, he places the interlock levers in the locked position and raises the "ready to fire" flag as soon as the muzzle doors are opened.

At actual firing, he sees that the spindles are out, after which he holds the firing key closed for 5 seconds. He then checks the poppet valve of the tube. When the poppet valve closes, he throws the "ready to fire" flag to the down position.

On the order to reload the tubes, the man between the tubes operates the interlock levers and adjusts the

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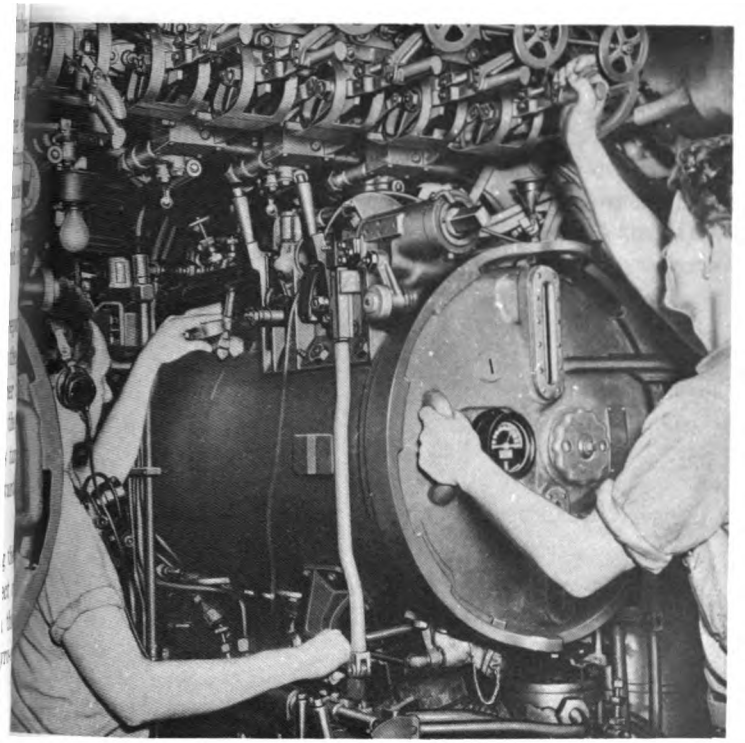

Figure 4–10.—Showing the man between the tubes at the order "Stand by." The drain valve operator is at the right.

spindles to their proper position for reloading. When a tube has been reloaded, he engages the spindles in the torpedo, places the interlock levers in the locked position, and again raises the "ready to fire" flag.

The man between the tubes is responsible for the prompt and accurate handling of the interlock levers, firing keys, and spindle settings, and for the proper closing of the poppet valve.

Reload Men

The reload crew consists of from three to five men, who stand by to reload torpedoes in the tubes when "re-

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load" is ordered. Figure 4–11 shows a member of a reload crew preparing to load a torpedo into a tube.

Any rating may be assigned to the reload crew. The reload man takes a station in the torpedo room, well clear of the tube breech, while awaiting orders to reload. In addition to helping with the reloading of torpedos, reload

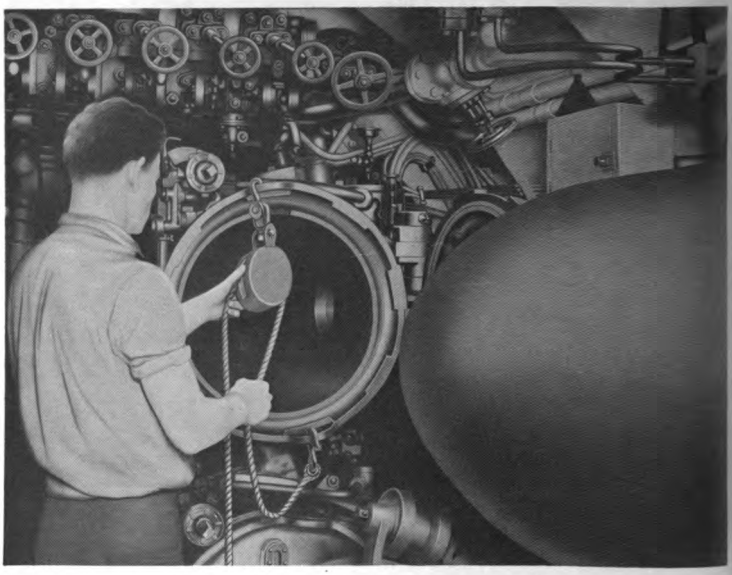

Figure 4–11.—Preparing to load a torpedo.

men are available for damage-control duties in the torpedo room to which they are assigned. The duty of the reload crew is to help the torpedo-firing personnel. Crew members give no supervision, but are closely supervised by the tube captain. The tube captain is responsible for seeing that reload men observe the safety precautions, that they have a thorough understanding of the reloading procedures, and of the possible damage that might result from mishandling of a torpedo.

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Firing Procedure

A typical underwater firing procedure is outlined in detail in OP 1085, *21-Inch Submerged Torpedo Tubes.* The OP describes the operating procedures for firing live torpedoes, dummy torpedoes, water slugs, inboard air charges, and mines. Although the firing procedures used on your submarine will probably differ somewhat from those outlined in OP 1085, the material in this publication is worth a careful study. (Make sure that you have the latest revision.)

You are not immediately concerned with submarine fire control, but we will give a brief outline of the underwater problem in chapter 5. The torpedo data computer used on submarines is the province of a fire control technician, and you will not be directly concerned with its operation or upkeep. It is similar in principle to the surface-ship torpedo director, although the answer it gives is GYRO ANGLE instead of SIGHT ANGLE.

Submarines receive their torpedoes in a modified fully-ready condition. The crew therefore needs only to recheck the final adjustments and make the final preparations to get the torpedo ready for firing. The routine depends on the type of torpedo being fired, and is given in the OP dealing with each specific torpedo.

RECOVERY OF EXERCISE TORPEDOES

After an exercise torpedo has been fired, a recovery team is assigned to recover it. Recovery of torpedoes is a tricky assignment, especially during rough weather.

Equipment

The recovery boat can be small. As a rule, the small motor whaleboat carried on destroyers is satisfactory. The necessary boat equipment includes:

1. Two nose lines of 3-inch manila for each torpedo.
2. Two tail lines of 3-inch manila for each torpedo. Each tail line ends in a slip noose of wire cable, so that it can be pulled taut around the tail.

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3. Two stop-valve tools (Tool No. 13–14). One is a spare.

4. Three or four marker buoys with attached mushroom anchors or similar weights.

5. One hoisting strap with attached securing line. (Marline is suitable for this purpose.)

6. One set of semaphore flags.

7. One pair of binoculars (7x50).

8. One BRAVO flag for hoisting in the bow of the boat as soon as the torpedo is recovered.

9. One propeller lock, with marline attached, for each torpedo, plus a spare.

The personnel required for recovery will vary, but usually one rated Torpedoman's Mate and two strikers will be sufficient. Navy boat discipline calls for one lifejacket per man as part of each boat's equipment. These should be put on as soon as possible after the boat is entered, and returned to their proper stowage after the boat is left. The kapok lifejacket usually provided is cumbersome, especially for the torpedo recovery personnel. Lifejackets of the Mae West type used by aviators, or the swim-master (belt type), are more suitable for the men handling the recovery equipment.

Recovery Procedure

When recovering a floating torpedo, always approach it FROM THE LEE SIDE. A lee approach lessens the chances of setting the recovery boat down on the torpedo, which might damage both the torpedo and the boat. Keep the torpedo clear of the boat propeller at all times.

Pass the nose line through the nose ring of the torpedo at the first opportunity. Then slide the noose of the tail line over the bitter end of the nose line, and secure the nose line well forward in the boat, hogging the torpedo in as close as possible. Work the tail line aft on the torpedo until it rests just forward of the tail vanes, then draw the noose tight. See figure 4–12.

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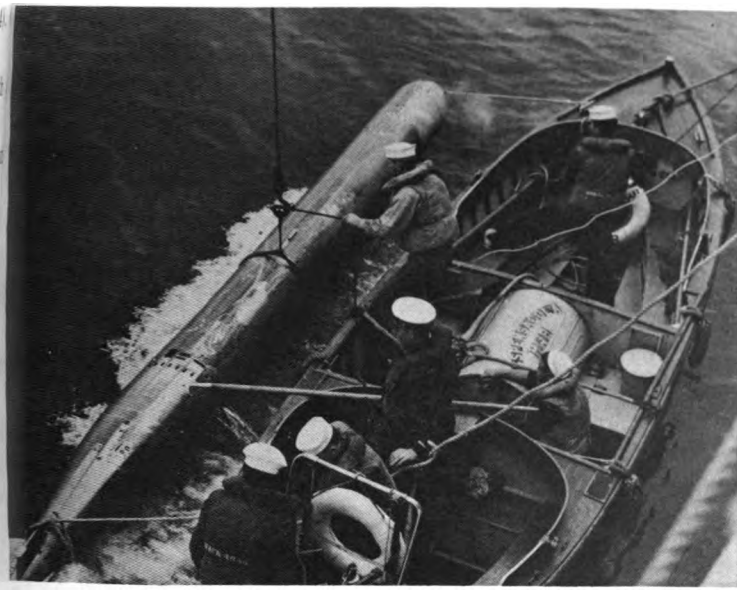

Figure 4–12.—Recovering a torpedo.

With the nose line secured to the boat well forward, kick the boat ahead slowly. The torpedo will tend to rise to a horizontal position alongside. This will make it easy to close the stop valve and put a lock on the torpedo propellers. (The propeller lock must be put on at the earliest possible moment.) Secure the tail line to the boat, hoist the BRAVO flag in the bow of the boat, and finish carrying out your recovery orders.

On some ships, the recovery crew may be directed to secure the torpedo to the side of the recovery boat that will be outboard when the boat has returned alongside the firing vessel or pier. In some cases, the hoisting cranes will not extend far enough over the water to reach the torpedo on the outboard side. Consequently, the recovery procedure must be altered to suit the hoisting gear.

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The hoisting strap must be put on the torpedo at its point of balance. The nose and tail lines will be PASSED, if possible (not cast), to the line handlers on the vessel or pier. The hoisting strap eye is attached to the hoisting crane hook. Personnel should then stand by to change the hoisting strap position if necessary. The

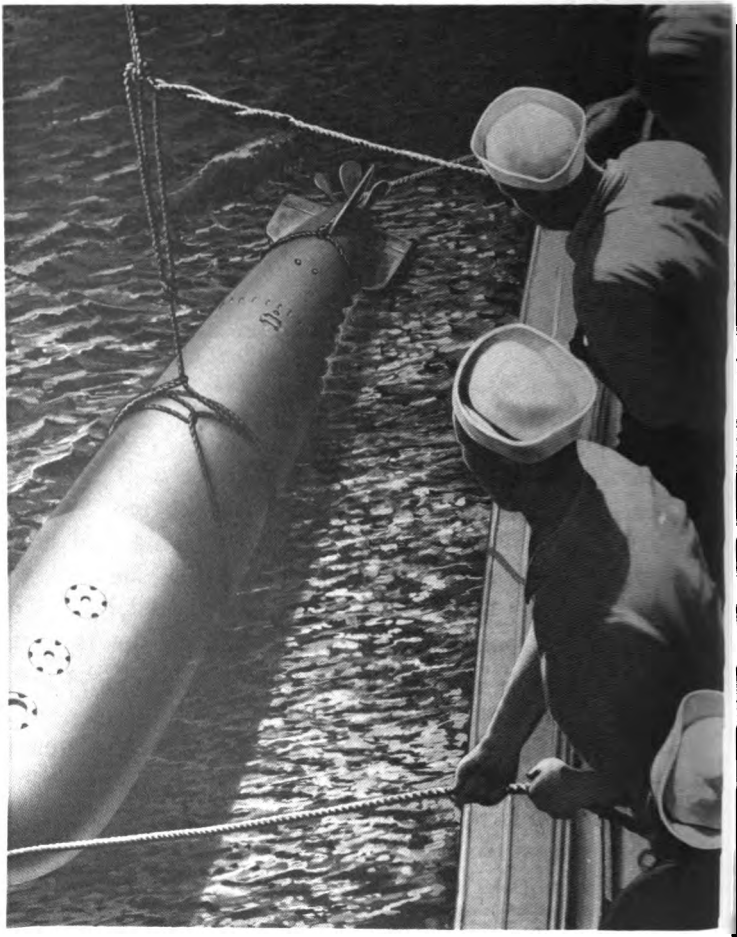

Figure 4–13.—Hoisting a torpedo from the water after recovery.

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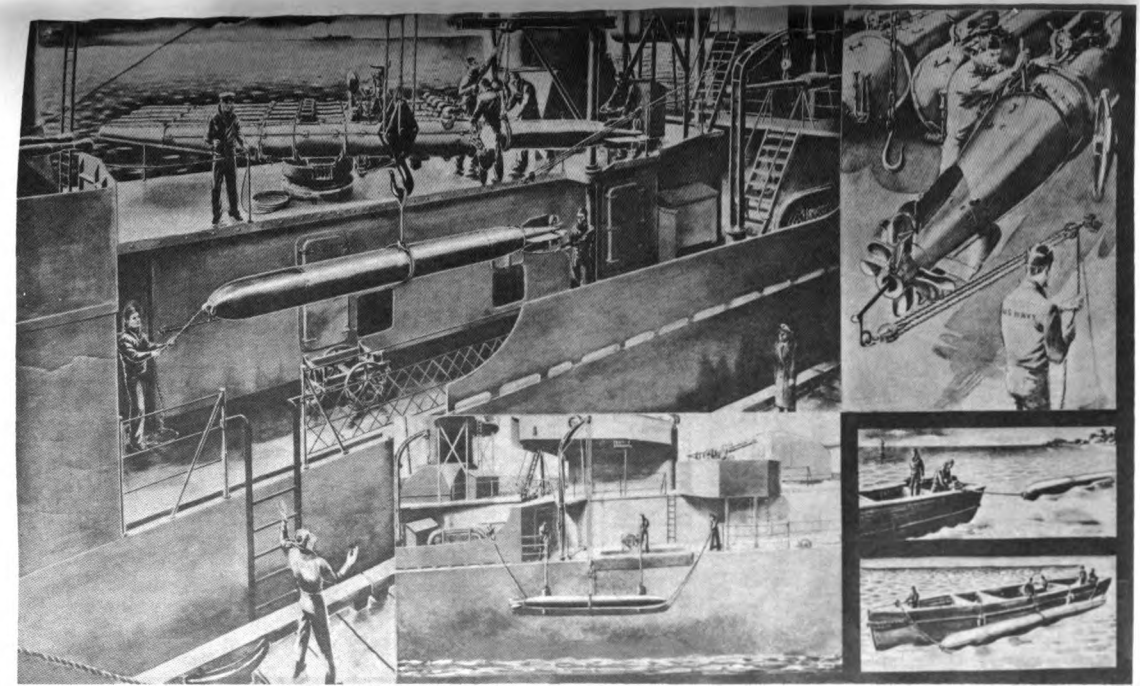

Figure 4–14.—Safe handling of torpedoes.

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boat coxswain will get orders to cast off and stand by when the torpedo is being hoisted from the water. Figure 4–13 shows a torpedo being hoisted after recovery.

The recovery boat should NEVER remain under the hoisting crane while the crane or hoisting gear is lifting the torpedo clear of the water. A power failure or carrying away of the hoisting gear might lead to personnel casualties and considerable damage to the torpedo and recovery boat.

After-Run Treatment

After the recovered torpedo is aboard, it needs prompt treatment to keep it in proper condition. The procedure is designed to prevent deterioration of the torpedo's parts until it can be prepared for firing again, or until it can be overhauled. The after-run treatment is the same in either case. The OP for the mark of torpedo you have fired and recovered contains a check-off list for its treatment after a run. Personnel must follow the check-off list exactly. A typical after-run treatment is outlined in *Torpedoman's Mate 3&2,* Volume 2.

Every person whose duty it is to supervise the handling of torpedoes (and of course that includes you) must take the utmost care to see that all regulations and instructions are rigidly observed. You must never permit any relaxation of vigilance. Remember that familiarity with any work, no matter how dangerous, is likely to lead to carelessness. Figure 4–14 shows the proper methods of recovering, hoisting aboard, and loading torpedoes. Study it carefully.

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QUIZ

1. Where can you find a discussion of torpedo firing from special launchers and from above-water fixed tubes?
2. Whv is it necessary for the mount captain to estimate target angle, target speed, and range?
3. During a torpedo attack, what is the principal duty of the director trainer in addition to training the director?
4. How is the tube mount usually trained after completion of an exercise firing? After completing a war shot?
5. On a submarine, where is the battle station of the tube captain?
6. What are the principal duties of the tube captain aboard a submarine during torpedo action?
7. What action must be taken if the poppet valve fails to close properly after firing? Who is responsible for this action?
8. What operation is performed on a tube firing valve during reloading of the tube?
9. What action should the gyro setter take if the gyro settings of the indicator-regulator fail to match in automatic control?
10. For what angle should the gyro-setting mechanism be set when it is turned off?
11. Who is responsible for operation of the interlock levers of submerged tubes?
12. Where can you find detailed instructions for operation of submerged tubes?
13. How does the output of the TDC differ from that of a torpedo director?
14. From which side should a floating torpedo be approached? Why?
15. What is the most important precaution to be observed while a recovered torpedo is being hoisted?
16. What is the purpose of the after-run treatment? Where can you find the necessary check-off lists?

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CHAPTER 5

TORPEDO FIRE CONTROL

The basic problem in torpedo fire control is simple. The answer we want is SIGHT ANGLE. Sight angle is the amount by which we "lead" the target ship. We can express the torpedo control problem as a simple question: In what direction must we fire the torpedo to make it strike the target?

Some of the corrections you find in the gun-fire control problem, such as those for range and altitude, and the many interior and exterior ballistic corrections, are not present in torpedo control. Range comes in only as a limiting factor; that is, the target must be within the effective range of the torpedo.

But there are a few factors that complicate the solution of the basic torpedo problem. For one thing, your own ship and the target ship are both in motion, and because of that the sight angle is constantly changing. It's often hard to determine target speed, target course, and target angle; and you need all these factors.

On top of that, the torpedo tends to "creep" through an angle that depends on the distance it covers and the latitude in which you fire it. To compensate for creep, you have to make a latitude correction. And finally, when you use gyro angle to produce a curved shot, you need a correction for the resulting advance and transfer.

The torpedo director is a calculator that combines all

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these values and corrections, and produces a solution to the torpedo problem. True, the answer it comes up with is constantly changing. But, at any given instant, the director gives you the right answer if you've put the right information into it. We discussed the torpedo director in Volume 2 of *Torpedoman's Mate 3&2*, NavPers 10156. You can find more information on the director, if you need it, in OP 1586. In this chapter, we

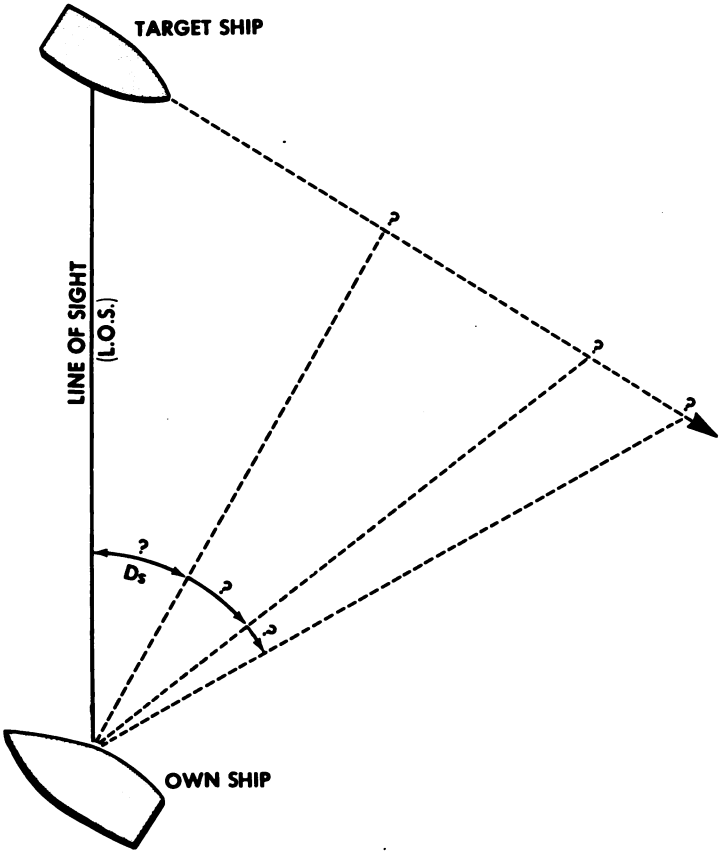

Figure 5–1.—The torpedo control problem.

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will try to give you a more complete understanding of the director by analyzing the problem it deals with.

After we've established a line of sight from the torpedo tubes to the target, as shown in figure 5–1, we can state the problem in another way: What angle should be formed between the line of sight and the torpedo track, so that target and torpedo will reach the same point at the same time? Line of sight, you remember, is abbreviated LOS. *Ds* is the sight angle. The point at which target and torpedo will meet is the POINT OF INTERCEPT.

Once we have found the value of the sight angle *Ds*, the problem is almost solved. We have only to add a few corrections, to convert *Ds* into the corrected sight angle *Dsk*, before firing the torpedo.

TRIANGLE OF TORPEDO FIRE

A solved torpedo control problem is a triangle, like the one in figure 5–2. The three points that determine the triangle are own ship, target, and point of intercept. The left side of the triangle in figure 5–2 is the line of sight; we can easily establish its direction, and if necessary we can measure its length by rangefinder or radar. The right side of the triangle is the torpedo track, and the far side is the target track. We don't know the length of either of these lines, but we know the ratio between them. The torpedo speed, of course, is known. We have several ways to estimate the target speed. Then, for example, if the torpedo speed is twice the target speed, the torpedo track will be twice as long as the target track.

The angle between the target track and the line of sight is the target angle. This angle is known.

Thus we know the value of several parts of the triangle. The answer to the problem—sight angle—is one of the unknown parts. We can find it by "solving" the tri-

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angle; that is, by using the known parts to find the value of the unknown parts.

Later in this chapter we'll show you three different ways to solve the triangle. One of these is a graphic method. This is the easiest one, but because of the limi-

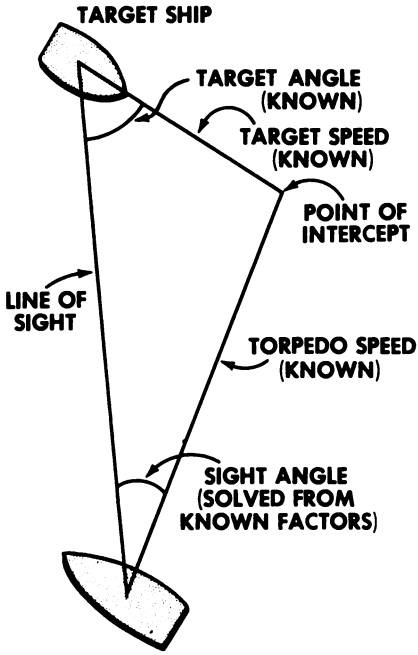

Figure 5–2.—A solved torpedo problem is a triangle.

tations of our tools it is also the least exact; we'll discuss it last. The other two solutions depend on simple trigonometry. If you're an expert in trigonometry, you can skip the next section; it's a short review of the subject. On the other hand if you've never studied trig at all, we suggest that you look it up in *Mathematics*, Volume 2, NavPers 10070.

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Every right triangle has one angle of 90°, and two smaller angles called acute angles. The size of these acute angles always depends on just one thing—the ratio between the lengths of the sides of the triangle.

Figure 5–3 illustrates this point. In this figure, angle C is a right angle; side a is exactly half as long as side c.

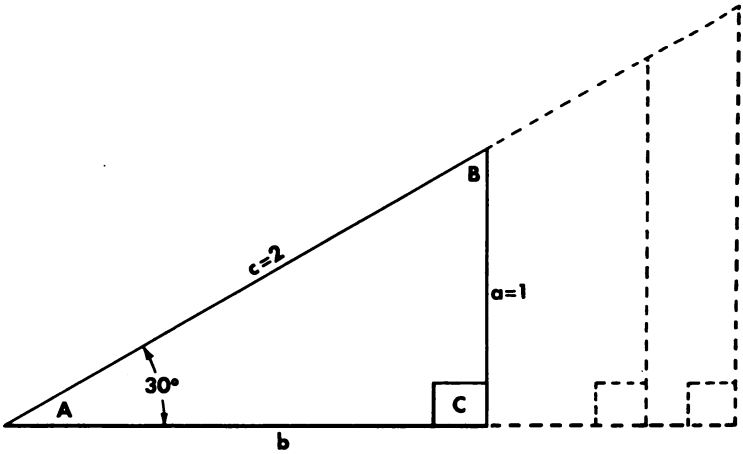

Figure 5–3.—Angle A is 30° when side a is half as long as side c.

Under these conditions, angle A can only be a 30° angle. And, conversely, as long as angle A is a 30° angle, side a must be half as long as side c. Notice in the diagram that it makes no difference how long the sides are in terms of feet, inches, or miles; as long as A is 30°, side a is half as long as side c.

If we should change the size of angle A, we would automatically change the ratio of side a to side c. (In other words, we would change the value of the fraction $\frac{a}{c}$.)

For any size of angle A, there is a corresponding value of $\frac{a}{c}$. The value of this fraction depends only on the size of

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angles, regardless of the actual length of the side in feet or miles.

For example, look at figure 5–4. We've increased angle A from 30° to 50°. And side a has increased from half the length of c to more than three-fourths the length of c. (The exact value of the fraction is 0.76604.)

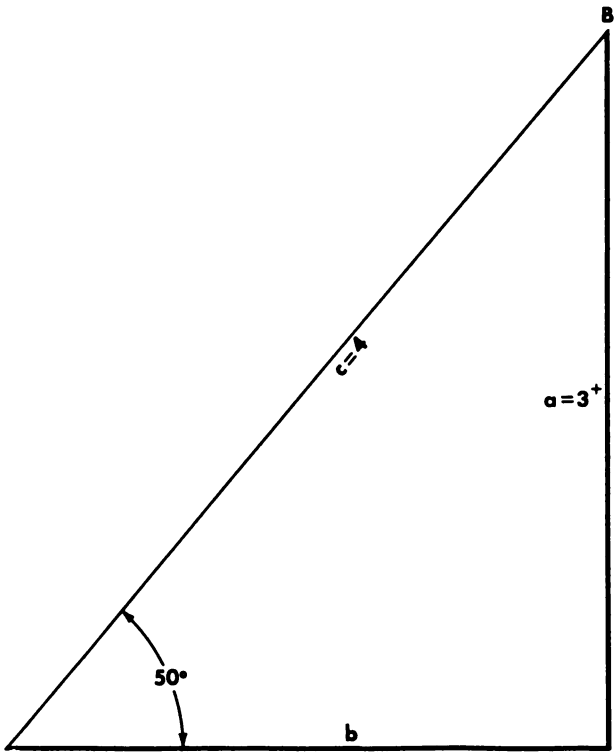

Figure 5–4.—For a 50° angle, the ratio of side *a* to side c is 3-plus over 4.

For one more example, look at figure 5–5. We have decreased angle A to 6°. Now side a is only a little more than one-tenth as long as side c. (The exact value of $\frac{a}{c}$ is 0.10453.)

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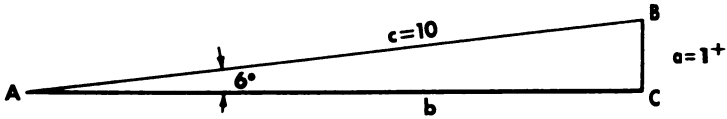

Figure 5–5.—For a 6° angle, *a* over c is a little more than 1 over 10.

To sum it up: in any right triangle, the value of the fraction $\frac{a}{c}$ (the ratio of the length of side *a* to the length of side *c*) depends only on the size of the angle—no matter how long the sides actually are. This ratio is called the SINE (written *sin*) of the angle. In the three diagrams above, this ratio is the sine of angle *A*, and is written "*sin A*".

We can state this principle in the form of an equation:

$$sin\ A = \frac{\text{length of opposite side}}{\text{length of hypotenuse}}$$

For the example shown in figure 5–3, we can write:

$$sin\ 30° = \frac{a}{c} = \frac{1}{2} = 0.5$$

Look at angle B in figure 5–3. What is the value of *sin B* in this drawing? We can use the principle stated above: the sine is the length of the opposite side divided by the length of the hypotenuse. Therefore:

$$sin\ B = \frac{b}{c}$$

Mathematicians have calculated the value of the sine for all angles, and have listed these values in tables of "natural trigonometric functions". You'll find a short table of trig functions on page 69 of *Mathematics*, Vol. 2, NavPers 10070. (Note that the sine is only one of several functions of an angle.) If you know the size of any angle, you can look it up in the table and find the value of its sine. Or if you know the sine, you can look it up and find the size of the angle.

The trigonometric functions are often useful in solving triangles—in finding the value of all parts of the triangle

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when only some of them are known. And the torpedo control problem, you remember, involves a triangle. After we take a closer look at the basic factors of the torpedo control problem, we'll show you how to solve it by trigonometry.

BASIC FACTORS OF THE PROBLEM

Let's say that your "own ship", as shown in figure 5–6, is a destroyer. You've sighted a target ship in the direction shown by the line of sight. You have, or can get, the following information:

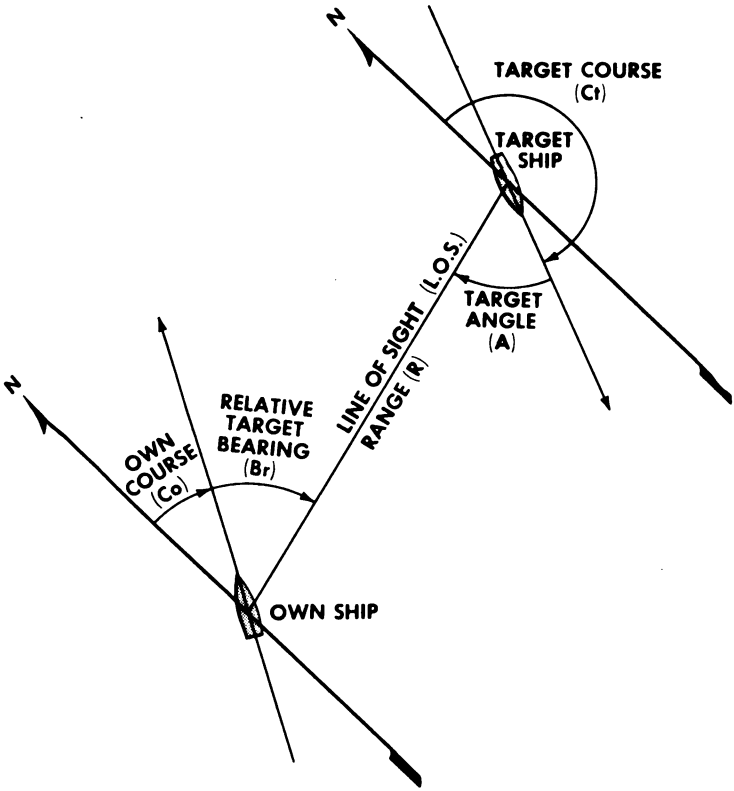

Figure 5–6.—Basic factors of the torpedo problem.

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1. TARGET ANGLE *(A)*. This is the angle between the fore-and-aft axis of the target ship and the line of sight. (As you can see, it's also the relative bearing of your own ship, as seen from the target.) It's measured clockwise from the target bow to the line of sight.

2. LINE OF SIGHT *(LOS)*. A straight line from the axis of the torpedo director to a point amidships of the target.

3. RELATIVE TARGET BEARING *(Br)*. The angle between the fore-and-aft axis of own ship and the line of sight, measured clockwise from the bow of own ship.

4. OWN COURSE *(Co)*. The angle between the north-south line and the fore-and-aft axis of own ship, measured clockwise from north to own ship's bow.

5. TARGET COURSE *(Ct)*. Course of the target ship, measured clockwise from true north to the target's bow.

6. RANGE *(R)*. The distance, in yards, from own ship to target; measured along the line of sight.

7. TARGET SPEED *(St)*. Estimated, in knots.

8. TORPEDO SPEED *(Sto)*. Known, in knots.

As you have seen, you don't actually need all of the above information to solve the torpedo problem. You can find the sight angle if you know three things: TARGET SPEED, TARGET ANGLE, and TORPEDO SPEED. With practice, you can estimate the target speed (largely from the size and form of the bow wave.) You know the speed of your torpedo. You will probably be told what the target angle is; if not, you can figure it out from the other information available to you.

To see how this can be done, take another look at figure 5–6. One of the north-south lines is drawn through the target ship, and one through your own ship. Because both of these lines point to true north, they are parallel. Notice that the line of sight (LOS) touches both north-south lines. If you've ever studied plane geometry, you know that when a straight line cuts two parallel lines, the two inner angles on opposite sides of the cutting line

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are equal. Find these two angles in figure 5–6; one of them is at the target, and one at own ship. At own ship, the angle is $Co + Br$. (Check this in the diagram.) At the target, the angle is $A + Ct - 180°$. (Check this carefully in the diagram.) Since these two angles are equal, we can say that

$$Co + Br = A + Ct - 180°$$

Now, if we solve that equation for A, we get

$$A = Co + Br + 180° - Ct$$

We suggest that you memorize that last formula. In a little while we will use it to solve an actual problem in torpedo control.

VECTORS

But before we consider an actual problem, we will have to explain one more term—VECTOR. A vector is a graphical presentation of any quantity that has both size and direction. It is drawn with an arrow tip to show its direction; its length is proportional to the size of the quantity it represents. We can use a vector to represent the speed and course of a ship, or of a torpedo.

Suppose you want to draw a vector to represent the speed and course of a target ship. The LENGTH of the vector will be proportional to the speed of the target ship. (You can use any convenient scale—for example 5 knots per inch—as long as you stick to the same scale throughout the problem.) The ANGLE the vector makes with some reference line (in this case the line of sight) shows the direction in which the target ship is moving.

In figure 5–7, St is a vector representing the speed of the target ship, and its course relative to the line of sight. From the end of St we have drawn a line, Xt, at right angles to the line of sight. Xt and Yt are COMPONENT VECTORS. Yt represents the distance the target ship travels ALONG the line of sight, and Xt rep-

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resents the distance it travels ACROSS the line of sight. As you can see, the three vectors *St*, *Xt*, and *Yt* form a right triangle, with the target angle *A* as one of its acute angles.

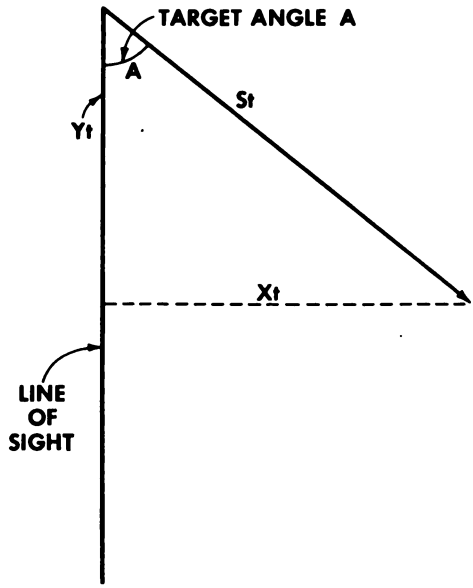

Figure 5–7.—Using a vector (St) to show speed and course of a target ship.

Now look at figure 5–8. Suppose that you have fired a torpedo at the target ship, and have hit it. In the diagram, figure 5–8, *Sto* is a vector representing the course and speed of your torpedo. *Yto* and *Xto* are the component vectors, representing the distance the torpedo has traveled along and across the line of sight. In figure 5–8 you can see two things. First, we have divided the triangle of torpedo fire into two right triangles. Second, since the torpedo hit the target, *Xt* and *Xto* are identical.

Now look at the right triangle at the target. We know two parts of the triangle: *A* and *St*. By using the

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formula for the sine of an angle, we can find the value of Xt. The formula says:

$$\text{Sine of an angle} = \frac{\text{opposite side}}{\text{hypotenuse}}$$

Therefore, in the triangle at the target ship,

$$\sin A = \frac{Xt}{St}$$

Solving that for Xt, we get

$$Xt = St \times \sin A$$

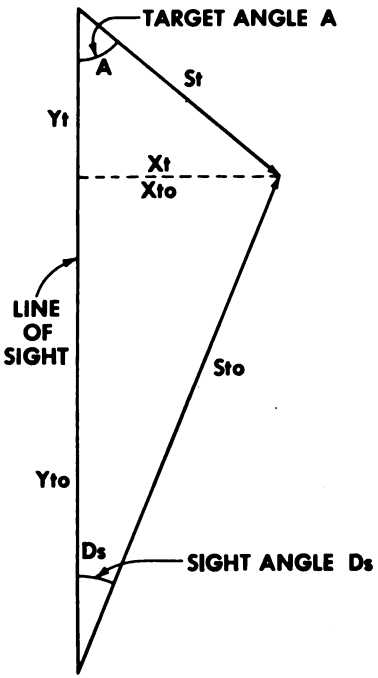

Figure 5–8.—Showing torpedo course and speed with vectors.

In the same way, we can solve the triangle at own ship to find the value of Xto.

$$\sin Ds = \frac{Xto}{Sto}$$

$$Xto = Sto \times \sin Ds$$

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If the torpedo is to strike the target, *Xt* must be equal to *Xto*. So now we can state the torpedo control problem in still another way: What sight angle must we choose to make *Xto* equal to *Xt?*

FIRING PROBLEM

Now let's apply what you've learned to solve the problem shown in figure 5–9. This figure is the same as 5–6, except that the known information is shown:

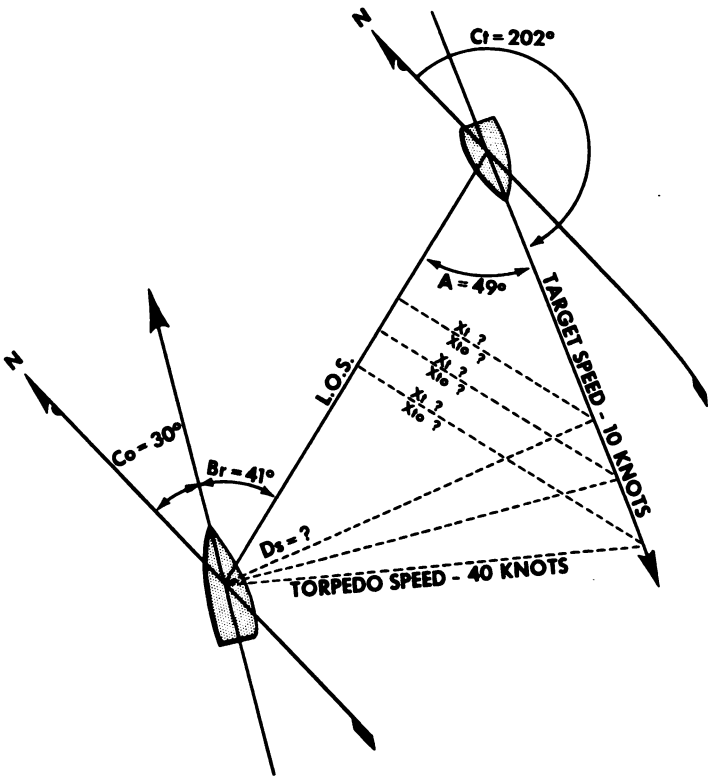

Figure 5–9.—When angle *Ds* is correct, *Xt* will be equal to *Xto*.

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1. Own course *Co is* 30°.
2. Relative target bearing *Br* is 41°.
3. Estimated target speed *St* is 10 knots.
4. Torpedo speed *Sto* is 40 knots.
5. Target course *Ct* is 202°.
6. Target angle A is 49°.

All of the above information is known, or can be calculated. For example, target angle *A* was computed from the formula:

$$A = Co + Br + 180^\circ - Ct$$

In figure 5–9, notice the dotted lines that run at right angles from LOS to the point of intercept of target and torpedo. Those lines represent target deflection *(Xt)*; we've drawn several of them because we do not yet know where this line belongs. *Xt*, you remember, is a vector; it's the component of target motion across the line of sight. If we choose the correct value for the sight angle *Ds*, we'll get a hit. The target and torpedo will reach the point of intercept at the same instant. When that is true, then the torpedo deflection, *Xto*, is equal to *Xt*.

Now, if you'll look back a few paragraphs, you'll see that the formula for *Xt* is:

$$Xt = St \times \sin A$$

Since we know the value of *St* and *A*, we can substitute in the formula:

$$Xt = 10 \times \sin 49^\circ$$

We can find the sine of 49° by looking it up in the table. We find that its value is 0.75471. Substituting in the formula, we get

$$Xt = 10 \times 0.75471 = 7.5471$$

A few paragraphs ago we also gave you the formula for *Xto:*

$$Xto = Sto \times \sin Ds$$

We know the value of *Xto;* it's the same as *Xt*, which we have just calculated. And we know the value of *Sto*—

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40 knots. When we substitute these two known quantities in the formula, we get

$$7.5471 = 40 \times \sin Ds$$

Solving for $\sin Ds$, we find that

$$\sin Ds = 0.18861$$

When we know the value of the sine of an angle, we can look it up in the table and find the size of the angle.

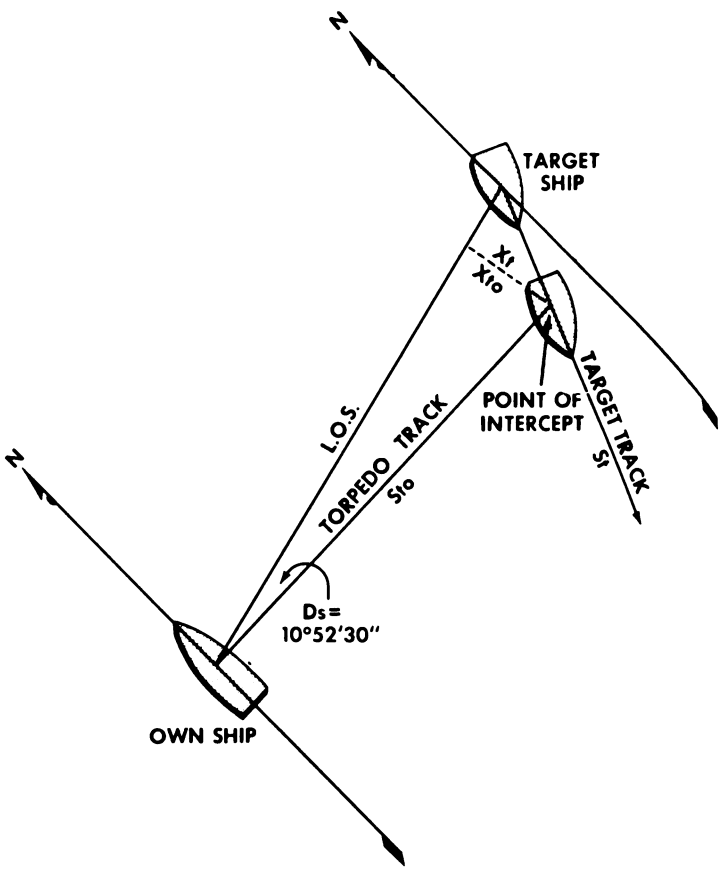

Figure 5–10.—Solution of the problem.

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The table shows that

$$Ds = 10° \; 52' \; 30''$$

We have found the value of the sight angle *Ds*, and we have therefore solved the problem. If we fire the torpedo at that angle, we should get a hit, as in figure 5–10.

Another Look at the Problem

The above solution may become a little clearer if we stop to see what will happen when we fire the torpedo at the WRONG sight angle. Suppose that everything remains as it's shown in figure 5–10, except that instead of calculating the correct sight angle we simply fire the torpedo at a sight angle of 25°. How will that effect the value of *Xt* and *Xto;* will they still be equal?

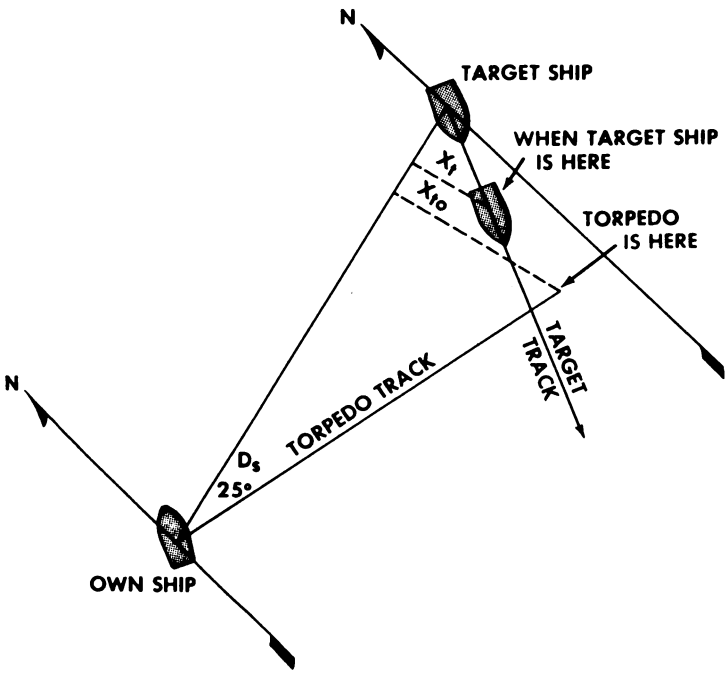

Figure 5–11.—Fired at a sight angle of 25°, the torpedo would miss the target ship.

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We haven't changed any of the conditions affecting the target ship. Therefore we already have the value of Xt—7.5471. But we've changed the value of Ds to 25°. Using the formula for Xto, we get:

$$Xto = Sto \times \sin Ds$$

$$Xto = 40 \times \sin 25° = 16.9$$

Now, since Xt is NOT equal to Xto, it's obvious that the torpedo and target ship will never meet. Figure 5-11 shows the result.

ANOTHER METHOD

Now look at the triangle in figure 5–12. This is not a right triangle; but the sines of the angles have a definite relationship to the length of the sides. This relationship can be expressed in an equation called the LAW OF SINES. The equation is:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

To put it in words: in any triangle, the lengths of the sides are proportional to the sines of the angles opposite them.

It may help you to remember the law of sines if we show you where it comes from. In figure 5–12 we've drawn a dotted line from point B perpendicular to side b. This line of course divides the triangle into two right triangles. We'll call the length of this line h.

Now if you remember the definition of the sine of an angle, you can see that

$$\sin C = \frac{h}{a}$$

and $$\sin A = \frac{h}{c}$$

or $$a \sin C = h$$

and $$c \sin A = h$$

Therefore:

$$c \sin A = a \sin C$$

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because things equal to the same thing are equal to each other. Now, if we divide both sides of the equation by *sin A sin C*, we get:

$$\frac{c}{\sin C} = \frac{a}{\sin A}$$

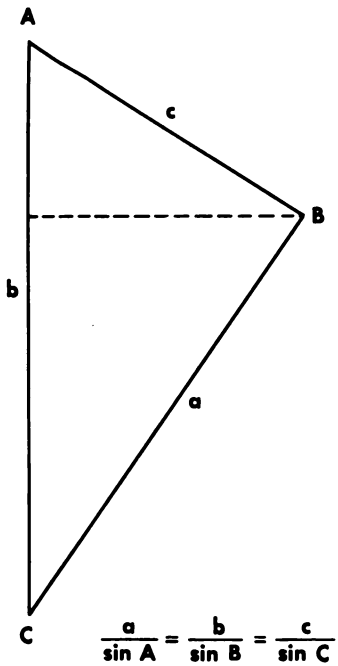

Figure 5–12.—The law of sines.

In the same way, we can include the relationship between side *b* and angle *B*, and thus obtain the law of sines:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

We suggest that you memorize that equation, because we're going to use it to solve a torpedo control problem.

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ANOTHER PROBLEM

Figure 5–13 illustrates the problem. We have the following information:

1. Own course *Co* is 45°.
2. Target course *Ct* is 221°.
3. Relative target bearing *Br* is 45°.
4. Target speed *St* is 23 knots.
5. Torpedo speed *Sto* is 33 knots.
6. Range *R* is 8,600 yards.

The information we want is basic sight angle *Ds*. But before we can find *Ds*, we have to know the target angle *A*. You can calculate it from the formula:

$$A = 180° + Co + Br - Ct$$

By substituting the known information in the equation, and solving, we find that *A* is 49°.

As you can see in figure 5–13, angle *A* is opposite the side that represents the torpedo speed—33 knots. And the sight angle, *Ds*, is opposite the side that represents the target speed—23 knots. Using the law of sines, and substituting the known values, we get:

$$\frac{33}{0.75471} = \frac{23}{\sin Ds}$$

If we solve that for *sin Ds*, and look up the result in the table of sines, we find that

$$Ds = 31°44'$$

If we fire a torpedo at a basic sight angle of 31°44′, we should get a hit. Let's double check and see. Now that we know the value of *Ds*, we can calculate several other values:

1. Target run *H*—the distance (in yards) traveled by the target during the time of the torpedo run.

2. Torpedo run *U*—the distance (in yards) actually traveled by the torpedo from the end of the tube to the point of intercept.

3. Time of torpedo run *Ta*—the time (in seconds) of torpedo travel to the point of intercept.

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4. Time of target run *Tt*—the time (in seconds) of target travel to the point of intercept.

Our first step is to find the remaining angle in the triangle. We already know that angle *A* is 49°, and angle *Ds* is 31°44′. Since the three angles of any triangle add up to 180°, we simply add the two known angles together and subtract the sum from 180°. Thus we find

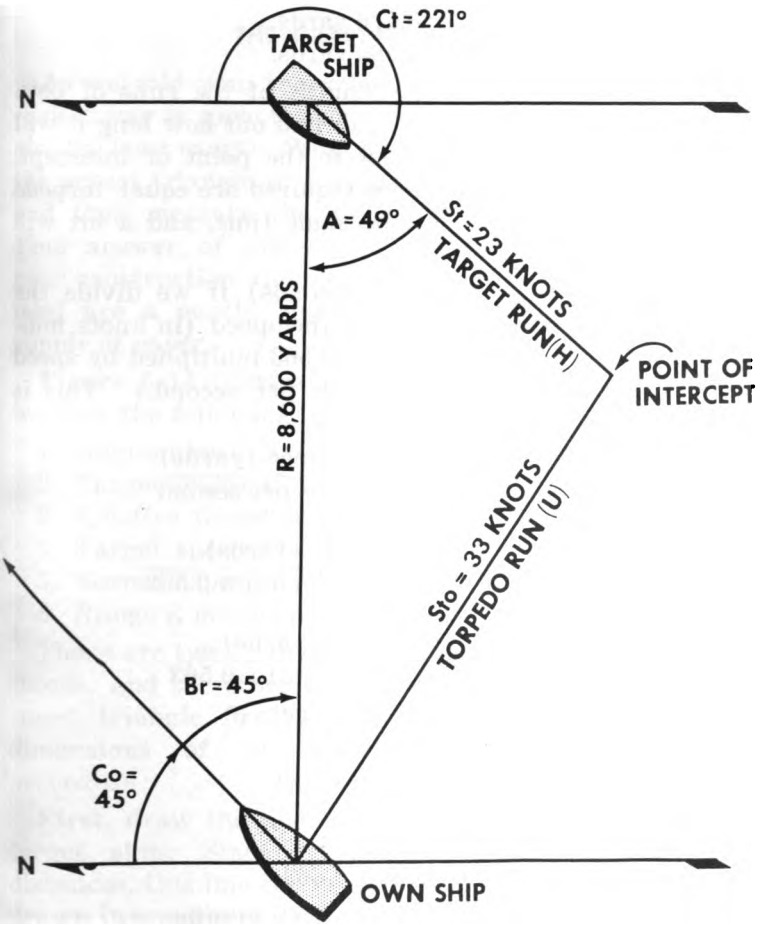

Figure 5–13.—Solving the torpedo control problem by the law of sines.

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that the unknown angle—let's call it angle Z—is 99°16′. Now we can solve for torpedo run U and target run H. Using the law of sines:

$$\frac{\text{U (torpedo run)}}{\text{sin A (target angle)}} = \frac{\text{R (range)}}{\text{sin Z}} = \frac{\text{H (target run)}}{\text{sin } Ds}$$

Substituting:

$$\frac{\text{U}}{0.75471} = \frac{8{,}600}{0.98695} = \frac{\text{H}}{0.52597}$$

Solving: U = 6,576 yards.
and H = 4,583 yards.

Now, since we have the lengths of the runs of both torpedo and target ship, we can find out how long it will take for each of them to get to the point of intercept. You can see that, if the times required are equal, torpedo and target will arrive at the same time, and a hit will result.

We can find the time (in seconds) if we divide the distance covered (in yards) by the speed (in knots multiplied by 0.563). (The figure 0.563 multiplied by speed in knots converts knots to yards per second.) This is the formula:

$$\text{time (seconds)} = \frac{\text{distance (yards)}}{\text{yards per second}}$$

or

$$Ta \text{ (seconds)} = \frac{\text{U (yards)}}{Sto \text{ (knots) x } 0.563}$$

and

$$Tt \text{ (seconds)} = \frac{\text{H (yards)}}{St \text{ (knots) x } 0.563}$$

Substituting in the formulas, we get:

$$Ta = \frac{6576}{33 \text{ x } 0.563}$$

and

$$Tt = \frac{4583}{23 \text{ x } 0.563}$$

Solving: Ta = 354.9 seconds or 5.9 minutes
Tt = 354.9 seconds or 5.9 minutes

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Since target and torpedo take exactly the same time to get to the point of intercept, we know that they will meet at that point. And the sight angle *Ds* that we calculated is therefore correct.

We suggest that you review the two mathematical methods for solving the torpedo problem, to get them firmly fixed in your mind before we take up the graphic method.

THE GRAPHIC METHOD

As we told you, the graphic method is probably the easiest way to solve the torpedo control problem, but it is also the least exact. What you're going to do is construct the actual triangle of torpedo fire on a sheet of paper, and then measure the sight angle with a protractor. Your answer, of course, can be no more accurate than your construction and measurement. The tools you will need are a pencil, ruler, dividers, protractors, and a supply of paper.

Figure 5–14 illustrates our problem. Let's say that we have the following information:

1. Own course *Co* is 30°.
2. Target course *Ct* is 210°.
3. Relative target bearing *Br* is 60°.
4. Target speed *St* is 12 knots.
5. Torpedo speed *Sto* is 27 knots.
6. Range R is 6,000 yards.

There are two triangles in figure 5–14; one is based on speeds, and the other on distances. You will draw the speed triangle first; you need that one to find the dimensions of the distance triangle. Here's the procedure:

First, draw the line of sight LOS from own ship to target ship. Since we are not yet concerned with distances, this line can be any length. In fact, it can be drawn in any direction, but to avoid confusion let us draw it in the direction we are given—90° (*Br* + *Co*).

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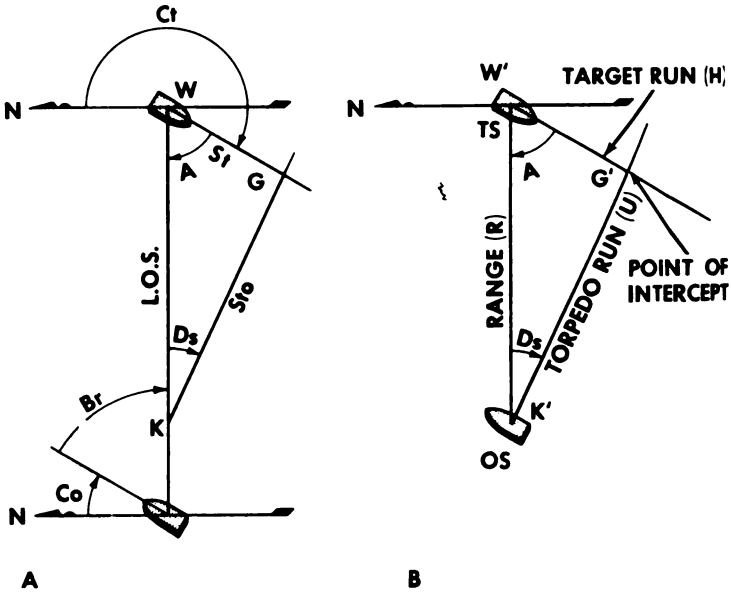

Figure 5–14.—The speed and distance triangles.

Next, draw a line representing the true course *Ct* of the target ship. This line can be any length, too, but it must be drawn in its proper position relative to LOS. Remember that the target course *Ct* is an angle measured from the north clockwise around to the bow of the target —in this case 210°.

Now, using any convenient scale, such as 10 knots to the inch, lay off the target speed *St*, which is 12 knots. Target speed now appears as the length *WG* in figure 54.

Next, using the same scale you used for target speed, set your dividers to the distance that represents torpedo speed. Using point *G* as a center, and a radius equal to torpedo speed, draw an arc across LOS. Call the point of intersection *K*, and draw the line *KG* to complete the speed triangle.

Now you have the basic sight angle *Ds*, which you can measure with your protractor. A torpedo set for a speed

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of 27 knots, and a launched on a course that makes an angle *Ds* with the line of sight, will intercept a target running at 12 knots, provided the target does not change course or speed during the torpedo run. (Actually, you'll have to make certain corrections to the angle *Ds*, as we pointed out earlier.)

Now you can draw the distance triangle shown in part B of figure 5–14. Begin by laying off the distance in yards, using any convenient scale—such as 2,000 yards to the inch—between own ship *OS* and the target ship *TS*. Lay off this distance along LOS. This is the range *R*. Next draw the target track, using the angle *Ct*. (You don't yet know the length of this line, so make it any convenient length.)

Measure angle *DS* in the speed triangle with your protractor. Using that angle, lay off the line *K'G'*. Where *K'G'* meets *W'G'* is the point of intercept *G'* for torpedo and target ship. The line *K'G'* represents the torpedo run *U* in yards, and the line *W'G'* represents the target run *H*, also in yards.

You can now measure the length of the target run *W'G'* and the torpedo run *K'G'* with the same scale you used to draw the range *R*—1 inch to 2,000 yards. It will then be easy to determine the time of torpedo run *Ta* and the time of target run *Tt*.

Notice that the speed and distance triangles have the same angles. As sketched in figure 5–14, they are also the same size. They need not be, however. We could have made *R* twice as long in the sketch by letting 1 inch equal 1,000 yards on our scale. But the results would be the same when we came to measure *W'G'* and *K'G'* by THAT scale, provided angle *Ds* was correctly drawn to begin with.

THE CORRECTIONS

You have solved the torpedo problem in three different ways; and, if you followed the explanations carefully, you know the answer we were looking for each time was the

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basic sight angle *Ds*. Theoretically, the problem is solved once you've found *Ds*.

But in actual fact it isn't; at least not always. Certain corrections will almost surely have to be applied to the basic sight angle, after which it becomes CORRECTED SIGHT ANGLE *Dsk*. These corrections are LATITUDE CORRECTION *Kla*, and INTERCEPT OFFSET *Osi*.

Let's consider latitude correction first. You know that torpedo gyros, like all gyros, have a tendency to creep. This tendency is one of the inherent properties of gyros; it's caused by the rotation of the earth. (You'll find a fuller explanation of creep in chapter 6, where we discuss the gyro in detail.) For the present, all you have to remember is that gyro creep causes the torpedo to curve to the right in north latitudes, and to the left in *south* latitudes.

Look at figure 5–15. Own ship sights the target ship along the line of sight as shown. The encounter takes place in north latitude. We find the basic sight angle, which would enable us theoretically to hit the target ship at position 1, and we fire the torpedo. The illustration shows what happens: We miss the target because the actual torpedo run is deflected to the right of where our calculations placed it. At the time the torpedo crosses the target path (at position 2), the target ship has not yet arrived. The amount by which the ACTUAL torpedo run is deflected from the CALCULATED run depends on the latitude in which the torpedo is fired, and on the length of the torpedo run.

As you can see from the diagram, we could get a hit by making the basic sight angle *Ds* smaller. We would make the angle smaller by an amount that would depend on both the latitude and the length of the torpedo run. In actual practice, we would do this by consulting tables and cranking the amount of correction into the torpedo director. The resulting tube train would then take care of matters.

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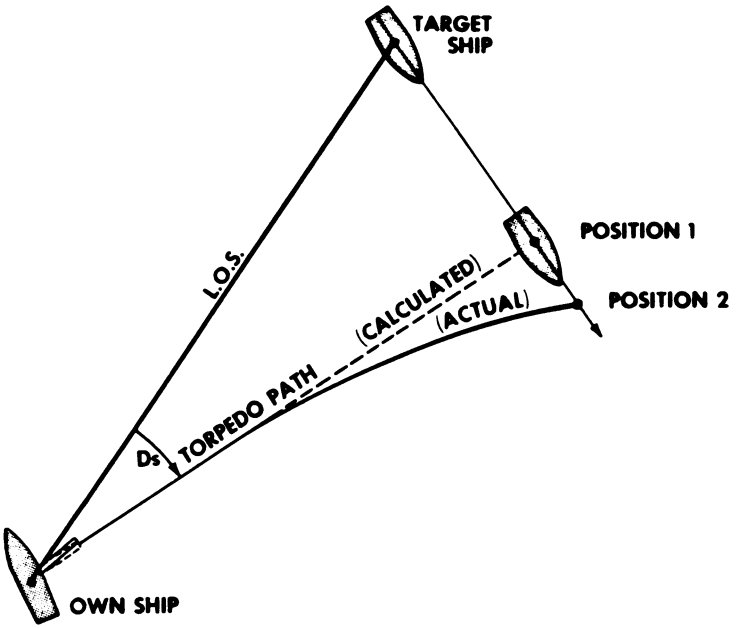

Figure 5—15.—Without latitude correction, the torpedo misses the target.

But here's another point to consider. Up to now, we have assumed that latitude corrections can be made only by introducing them into the director (or into the tube train). We have also assumed that torpedo gyros are so adjusted that torpedoes run straight only at the equator.

Neither of these assumptions is necessarily true. Latitude corrections can be made in another way; and, when they are made the other way, the torpedo runs straight at the latitude for which the correction is made. It curves to the right north of THAT latitude, and it curves to the left south of it.

You have probably had plenty of actual experience in balancing the gyro by adjusting the balance nut. You know that when the balance nut is 1.5 turns from the hard-up position, the gyro is in STATIC balance. When the gyro is in static balance, the torpedo it steers will run

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straight at 0° latitude; it will curve right in north latitudes, and left in south latitudes.

But if the balance nut is set at 1.9 turns from the hard-up position, the torpedo will run straight at the latitude of Newport, Rhode Island (about 41°N); it will curve right north of that latitude, and will curve left south of it. The gyro will be in RUNNING balance at 41°N. In fact, the balance nut of the gyro can be adjusted for any desired latitude, so that for practical purposes the torpedo will run straight at that latitude. The necessary adjustments can be made whenever a vessel carrying torpedoes moves to a latitude different from that for which the balance nut is set.

But under service conditions it may be impractical to keep the gyro balance nuts set for whatever latitude the ship may be in when the torpedoes are fired. A ship can change latitude rapidly, and you don't have time to draw the torpedoes out of their tubes and adjust the balance nuts every few hours. For that reason, modern torpedo directors have a hand crank for making the necessary latitude correction. Tables and formulas are available to determine how much correction should be made when the ship fires its torpedoes in other than "balance latitude." All you have to do is to read the proper figures from the tables, and crank the values into the director.

If you are interested in the formulas used to calculate the necessary amount of correction, there are two of them. You use whichever formula you need, according to the explanation given below. Here are the formulas:

$$Kla = \frac{0.0037 \times R \times (\sin L2 - \sin L1)}{Sto} \qquad (1)$$

$$Kla = \frac{0.0037 \times R \times (\sin L2 + \sin L1)}{Sto} \qquad (2)$$

where

Kla = latitude correction in *degrees*.
R = torpedo run in yards.

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$L2$ = firing latitude.
$L1$ = balance latitude.
Sto = torpedo speed in knots.

Here are the rules for using the two formulas:

RULE 1.—If the firing latitude $L2$ is NORTH of the balance latitude $L1$, the tube is indexed to the LEFT. The amount (in degrees) of left index is given by formula 1 when $L2$ and $L1$ are on the same side of the equator, and by formula 2 when $L2$ and $L1$ are on opposite sides of the equator.

RULE 2.—If the firing latitude $L2$ is SOUTH of the balance latitude $L1$, the tube is indexed to the right. The amount (in degrees) of right index is given by formula 1 when $L2$ and $L1$ are on the same side of the equator, and by formula 2 when $L2$ and $L1$ are on opposite sides of the equator.

In actual practice, you won't worry about the formulas or how to use them. If you're firing with the director, latitude correction is shown (in degrees) on the outer dial of the intercept offset group. All you will do is this: If you are firing in a latitude NORTH of the balance latitude, you will turn the latitude-correction dial the proper amount toward the "N" marked on the dial. If you are firing in a latitude SOUTH of the balance latitude, you will turn the dial the proper amount toward the "S." The proper amount of correction will be indicated in tables, and will be furnished you either directly or by the CIC.

But you will have to take one more step before your job is finished. After you have turned the latitude-correction dial the proper amount in the proper direction, you turn the inner dial (the intercept-offset dial) until its zero mark is matched with the zero mark on the outer (latitude-correction) dial. You do that if you're NOT using any intercept offset *Osi*.

But the skipper may decide, on the basis of past experience, that the target ship is going to maneuver. It

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may change either course or speed (or both) after the problem has been set up in the director. At the last moment, the skipper may order a small change in the sight angle, to take care of the expected maneuver. This change is the intercept offset.

Look at figure 5–16. Suppose the problem is set up so that a torpedo fired at a certain sight angle *Ds* will intercept the target at point 1, PROVIDED the target does not change its speed or course. Suppose, however, that the skipper decides the target will probably change course

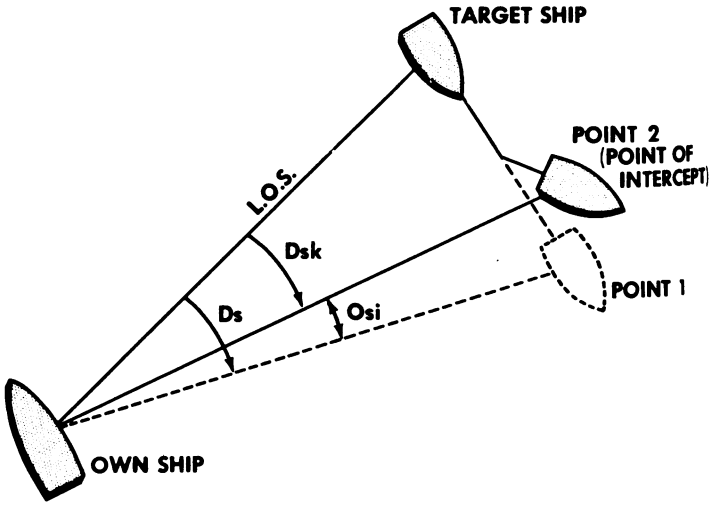

Figure 5–16.—Intercept offset takes care of target-ship maneuvering.

and speed so that, instead of moving to point 1, it will move to point 2. As you can see, the change in target speed and course will call for a change in sight angle. You can introduce this change into the director by setting the inner dial of the intercept-offset group either to the right or left of the zero mark on the latitude-correction dial (depending on which way the sight angle is to be

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changed). This correction can be introduced without changing any of the other factors in the problem.

It is possible, of course, that latitude correction may exactly cancel the intercept offset. In that case, corrected sight angle would be the same as basic sight angle. A number of combinations could occur, so that corrected sight angle might be either larger or smaller than the basic sight angle, or identical with it.

TRACK ANGLE

One more factor is important in determining whether you will get a hit with your torpedo. That factor is track angle *Btr*. As you can see in figure 5–17, it's defined as the angle between the fore-and-aft axis of the target and

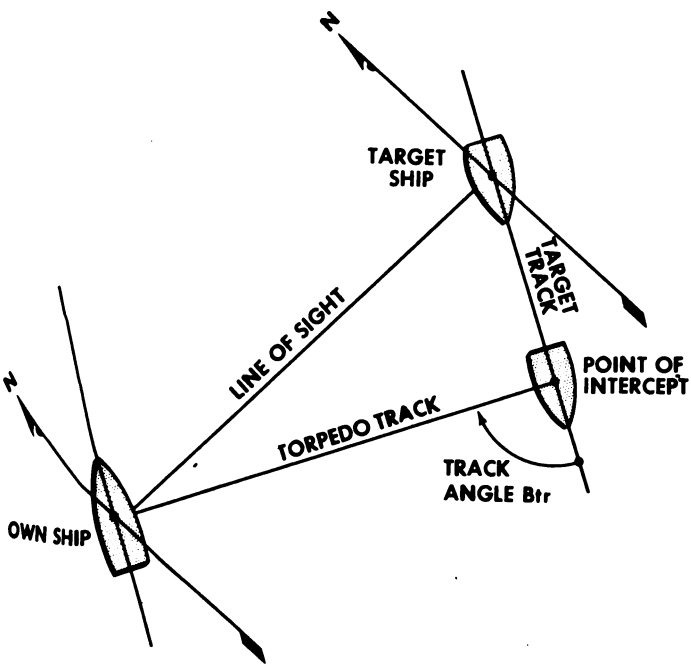

Figure 5–17.—Track angle *Btr*.

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the final track of the torpedo, measured clockwise from the target's bow. (It's also defined as the angle between the target course and the reverse course of the torpedo, measured clockwise from the target bow—which is another way of saying the same thing.)

The ideal track angle is 90° or 270°, because the target ship is then squarely broadside when the torpedo arrives. A 90° track angle is shown in figure 5-17. Such a track angle forces the target ship to do the greatest amount of dodging to escape the torpedo.

The poorest track angle is 0° or 180°. With either of those angles, the torpedo would go head on for the bow or stern of the ship, and a miscalculation of only a few feet would give you a miss. In general, firing ships jockey for positions that will give them the most favorable track angle. The skipper, in other words, tries to put his ship in the position at which the target angle will result in the desired track angle.

On the other hand, by combining tube train and gyro angle, the torpedo can be made to go at almost any angle away from the line of sight. If the tactical situation permits, the skipper generally tries to choose a target angle that will result in the best track angle. Then the sight angle is determined accordingly.

But the skipper may have no choice. He may not have time for maneuvering, or maneuvering may be dangerous. In such cases, the sight angle that comes up in the solution of the problem must be used, regardless of whether or not the track angle is favorable.

SUBMARINE TORPEDO CONTROL

Up to this point, we have discussed torpedo control from the viewpoint of destroyers. Now we'll look at some of the differences between the surface-ship problem and the submarine problem.

The chief practical difference is this: In surface-ship torpedo control you combine all the known data to find

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ıe sight angle *Ds*. But in submarine torpedo control, ıe answer you want is the correct gyro angle *G*. In ubmarine torpedo control, *G* is the angle between the ore-and-aft axis of own ship and the FINAL track of the orpedo, measured clockwise from own ship's bow. 'igure 5–18 shows three examples of gyro angle. Note

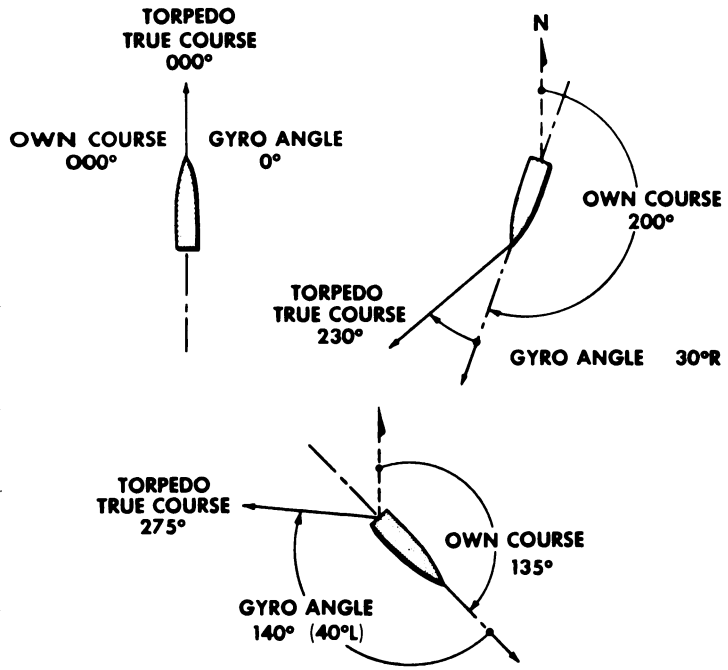

Figure 5–18.—Three examples of gyro angle.

that gyro angle combined with own ship's course determines the TRUE torpedo course.

At the upper left in figure 5–18, own ship is heading due north (000°). A torpedo is fired straight ahead. The gyro angle is 0°, and the true course of the torpedo is 000°. If own course is 200°, as at the upper right, a

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torpedo fired with a gyro angle of 30° will take a true course of 230°. The lower diagram shows a stern shot fired with a 40° left gyro angle (140° measured from the bow). The torpedo's true course will then be 275°.

Gyro angle is also used by destroyers in torpedo fire control, where it is called BASIC GYRO ANGLE *Bgy*, and is measured from the tube axis. In the surface-ship problem, curved fire is accomplished with a combination of tube train and basic gyro angle. With a trainable tube mount, a gyro angle is not always necessary in the surface problem. In straight fire, the tube train determines the torpedo's course.

But submarines seldom use straight fire, because submarine tubes are fixed. The entire vessel would have to be trained to bring the tubes into the proper firing position. Since maneuvering the vessel is often impracticable, the torpedo must be made to curve onto the correct course after it leaves the tube.

Torpedo control on submarines therefore consists in finding the proper gyro angle, so that the torpedo's final course will bring it to a point on the target track at the same instant the target reaches that point. Sight angle, as the term is used in surface torpedo control, is not in the language of submerged torpedo warfare.

Figure 5–19 shows a typical submarine torpedo-control problem. Notice that the torpedo travels straight for a short distance after it emerges from the tube. Then it begins to curve through an arc, the length of which depends on the gyro angle. Finally, it takes up a straight course that brings it to the point of intercept with the target.

The chief complicating factor in the submarine torpedo control problem is that the torpedo run includes an arc, together with two straight segments. In actual practice, the correct gyro angle (which determines the length of the arc) is found by the torpedo data computer. In effect the torpedo data computer measures the length of the

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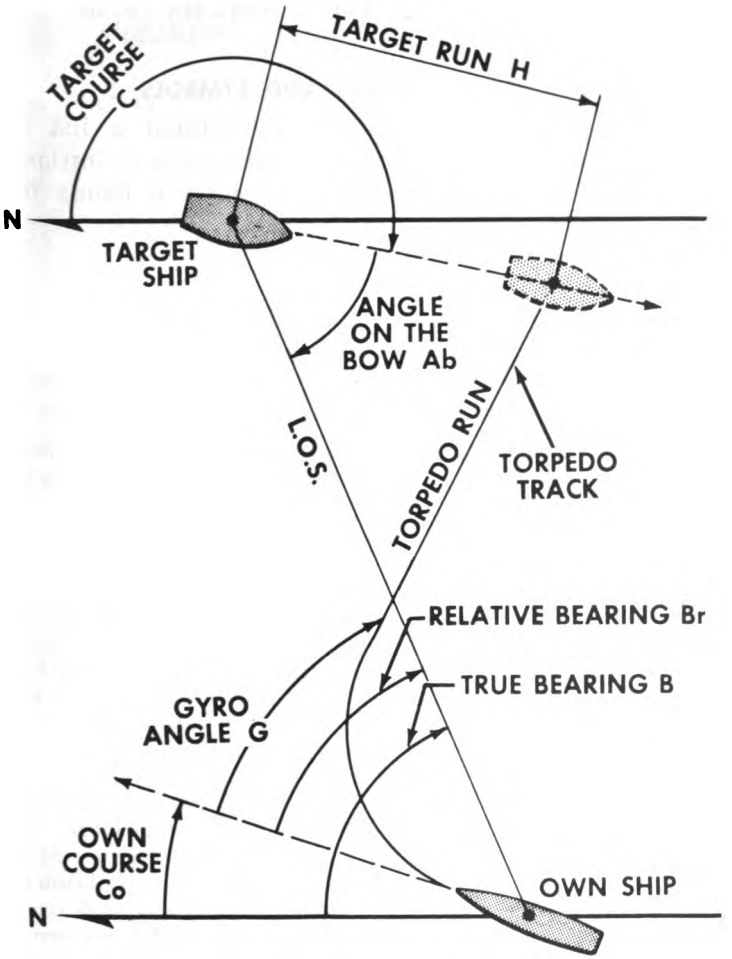

Figure 5–19.—Chief factors in submarine torpedo control.

curved segment of the torpedo run, and indicates the corresponding gyro angle to be used in order to make the total run take exactly the same time as the target run. When these two times are equal, a hit will result.

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The torpedo data computer is discussed in *Torpedoman's Mate 3 & 2, Vol. 2,* NavPers 10156.

GLOSSARY OF TERMS AND SYMBOLS

In *Torpedoman's Mate 3&2,* we printed a list of torpedo control terms, with their symbols and definitions. We'll repeat that list here, so you'll have it handy for reference.

Symbol	*Term*	*Definition*
(None)	FIRING POINT	The point where the torpedo begins its run. Broadly, it's the position of own ship at the instant of firing.
LOS	LINE OF SIGHT	A straight line from the axis on which the torpedo director rotates to the point of aim on the target.
(None)	POINT OF AIM	The point on the target that you intend to hit with the torpedo.
(None)	TORPEDO TRACK	The path of the torpedo through the water. When you fire a torpedo with zero gyro angle, its path will be a straight line. When you fire with gyro angle, the path will be made up of two straight lines with an arc between them. After it's fired from the tube, the torpedo will travel for a short distance in a straight line. This distance is called the REACH. At the end of the reach, the torpedo will begin to turn through the angle you've set on its gyro. While it's turning its path is an arc of a circle. After it has turned through the gyro angle, it will again travel in a straight line. This final straight line is called the FINAL TRACK of the torpedo.
Bt	TARGET ANGLE	The angle between the fore and aft axis of the target and the line of sight. It's measured clockwise from the target's bow.

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Symbol	Term	Definition
B	TRUE TARGET BEARING.	The angle between the north-south line and the line of sight. It's measured clockwise from north.
Bgy	GYRO ANGLE	The angle between the axis of the torpedo tube and the final track of the torpedo. It's measured clockwise from the torpedo tube.
Br	RELATIVE TARGET BEARING.	The angle between the fore-and-aft axis of own ship and the line of sight. It's measured clockwise from ship's bow.
Bto	TORPEDO COURSE	(A more accurate term for this would be RELATIVE TORPEDO COURSE.) The angle between the fore and aft axis of own ship and the final track of the torpedo. It's measured clockwise from own ship's bow.
Btr	TRACK ANGLE	The angle between the fore-and-aft axis of the target and the final track of the torpedo. It's measured clockwise from own ship's bow.
Btu	BASIC TUBE TRAIN.	The angle between the fore-and-aft axis of own ship and the axis of the torpedo tube mount. It's measured clockwise from own ship's bow.
Co	OWN SHIP COURSE	The angle between the north-south line and the fore-and-aft axis of own ship measured clockwise from north to own ship's bow.
Ct	TARGET COURSE	The angle between the north-south line and the fore-and-aft axis of the target ship. It's measured clockwise from north to the target ship's bow.
Ds	BASIC SIGHT ANGLE.	The angle from the line of sight to the FINAL TRACK of the torpedo, measured clockwise from the line of sight.
Dsk	CORRECTED SIGHT ANGLE.	The basic sight angle with latitude correction and intercept-offset correction applied.
H	TARGET RUN	The distance the target travels during the time of torpedo run.

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Symbol	*Term*	*Definition*
Kla	LATITUDE CORRECTION.	A slight correction to the sight angle, to compensate for the creep of the torpedo gyro. The size of the correction depends on the latitude, the time of the torpedo run, and the balance nut setting on the torpedo gyro. If the gyro is balanced for the latitude in which the torpedo is fired, the correction is zero.
Osi	INTERCEPT OFFSET.	A change in the sight angle to allow for an expected change in target course or target speed during the torpedo run.
Q	SPREAD ANGLE	The angle between the final tracks of any two adjacent torpedoes fired in salvo from the same tube mount.
R	RANGE	The distance, in yards, from own ship to target at any instant.
So	OWN SHIP SPEED	Speed of own ship in knots.
St	TARGET SPEED	Speed of the target, in knots.
Sto	TORPEDO SPEED	The average speed of the torpedo, in knots, from the instant of firing to the time it strikes the target.
Ta	TIME OF TORPEDO RUN.	The time between the instant of firing and the instant the torpedo crosses the target track (when torpedo-speed correction is zero).
Tt	TIME OF TARGET RUN.	The time between the instant of firing and the instant the target crosses the torpedo track.
U	TORPEDO RUN	The actual distance, in yards, that the torpedo travels, from the end of the tube to the point where it crosses the target track.
Xt	TARGET DEFLECTION.	The component of target speed at right angles to the line of sight.
Xto	TORPEDO DEFLECTION.	The component of torpedo speed at right angles to the line of sight.

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QUIZ

1. Where can you find information on the torpedo director?
2. The answer to the surface torpedo control problem is an angle. Name this angle and give its symbol.
3. In a right triangle, what is the formula for the sine of either acute angle?
4. If you know the size of an angle, how can you determine the sine of the angle?
5. If you know the sine of an angle, how can you determine the size of the angle?
6. Define the target angle in two ways. What is its symbol? In what direction is it measured? Between what two points?
7. You can solve the torpedo control triangle if you know only three things. What are they?
8. State the formula for target angle, in terms of known quantities.
9. What is a vector?
10. Define *Xt* and *Xto*.
11. When the sight angle is correctly chosen, what is the relation between *Xt* and *Xto?*
12. From memory, write the formula for the law of sines. (Assume that the three sides of the triangle are a, b, and c, and that the angles opposite these sides are, respectively, A, B, and C.)
13. Why is the graphic solution less accurate than the others?
14. What two corrections must be applied to *Ds* to convert it into *Dsk?*
15. Why can't we depend on the balance nut setting to take care of creep?
16. Who determines the value of *Osi*, and what is its purpose?
17. Define track angle *Btr*.
18. What track angles are most likely to result in a hit? Why?
19. In surface torpedo control, the answer to the problem is *Ds*. What is the answer to the submarine torpedo control problem?
20. If you know own ship's course and the gyro angle, how do you find the true course of the torpedo?

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CHAPTER 6

GYROS

In chapter 10 of *Torpedoman's Mate 3&2,* volume 1, NavPers 10155, we gave you a short introduction to the torpedo gyro. That chapter introduces the two basic properties of a gyro: RIGIDITY IN SPACE, and PRECESSION. It tells how the gyro is mounted in the torpedo, and explains its tendency to creep (except at the equator). It would be a good idea to review that chapter now, if it isn't fairly fresh in your mind.

In the present chapter we will explain briefly WHY a gyro acts the way it does. We will review the construction of a Gyroscope Mk 12 Mod 3, and introduce the subject of gyro maintenance and overhaul.

GYRO ACTION

In order to follow a preset course to its target, the torpedo must have a fixed reference to steer by. Because the fast-spinning torpedo gyro has the property of RIGIDITY IN SPACE, the direction of its axis remains fixed during the torpedo run, and can thus serve as a fixed reference for steering. The torpedo can steer itself in the direction its gyro axis is pointed, because its steering mechanism can automatically correct any deviation from that course. Or, if you set in a gyro angle before firing, the torpedo will maintain a course a fixed number of degrees to right or left of the steering reference provided by the gyro axis.

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Because of its rigidity in space, any rapidly spinning object with no outside forces acting on it will keep its axis of spin pointed always in the same direction IN SPACE. What do we mean by that? A fixed direction on the earth is by no means fixed in space, because the earth turns on its axis every 24 hours. It makes a complete revolution around the sun every year. And the sun itself is moving, taking the earth and planets along with it. Because of these motions, the expression "fixed direction in space" has no exact meaning. But for all practical purposes we can say this: a line from the earth to a star is a fixed direction in space. Therefore, if the axis of a spinning gyro is pointed at a star, it will follow that star as the earth turns.

Now, if you will remind yourself how stars appear to move, you will have a clear picture of a gyro's "rigidity in space." The position of the north star appears to remain fixed. (Actually, its apparent movement is an extremely small circle.) Stars near the north star appear to move in circles around it, making one revolution every 24 hours. Stars at some distance from the north star appear to rise in the east, swing overhead, and set in the west.

Since the axis of a spinning gyro will follow any star it's pointed at, you can see that its apparent motion depends on the direction it has to start with. This apparent motion of the gyro axis is the motion we call CREEP. Although you're probably accustomed to thinking of gyro axis creep as a motion to right or left, it's actually a motion along an arc of a circle. We can say that gyro creep has two components—up-and-down as well as right-and-left.

The maximum time for a torpedo run is a very small part of 24 hours. During the run, the gyro axis will creep along a correspondingly small part of a circle. In this time the up-and-down creep will have no significant effect on the torpedo's course. But the left-and-right

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creep will often be enough to make the torpedo miss its target. For that reason, left-and-right creep must be corrected by positioning the balance nut of the torpedo gyro. Moving the balance nut from the position of static balance will apply an upward or downward force to the gyro axis. That will make the gyro undergo PRECESSION toward the right or left. Precession, as you probably remember, is the movement of a gyro axis at a RIGHT ANGLE to the direction of any force applied to it. For any given latitude, we can adjust the balance nut so that it will apply just the right amount of force to make the precession cancel the creep.

If you will think of the stars again you'll see why creep depends on latitude, and why it's zero at the equator. Suppose that, at the instant of firing, the axis of your torpedo gyro is pointed at the north star. Since the north star has practically no apparent motion, the gyro will have practically no creep. You could eliminate the creep problem if you could always fire the torpedo with its axis pointed at the north star.

But that isn't practicable. The north star lies above the horizon in northern latitudes, and below it in southern latitudes. For practical reasons, it is desirable to fire the torpedo with its gyro axis horizontal. To see why, assume for a moment that it's possible to fire a torpedo at the north or south pole. The gyro axis, if it's pointed at the north star, will be pointed straight up and down. A change in torpedo course will produce no change in the relative direction of the gyro axis. Gyro sensitivity, for steering purposes, would be zero at the poles and maximum at the equator, with intermediate values in between.

At the equator, the north star lies on the horizon. Let's say that you fire a torpedo, at the equator, with its gyro axis pointed north. Since the gyro axis is pointed at the north star, it will have no apparent movement, either horizontally or vertically. Creep will be zero. If

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you fire a torpedo eastward at the equator, its gyro axis will follow the path of a star rising in the east passing up overhead. Horizontal creep is still zero. Vertical creep is now maximum (but still too small to affect torpedo steering).

At the poles, the stars appear to move in circles parallel to the horizon. At 90° latitude, vertical creep is zero. But horizontal creep is at a maximum, and would require a maximum setting of the gyro balance nut for correction. Intermediate latitudes result in intermediate degrees of horizontal creep. The higher the latitude, the more the creep, and the greater the correction required for the balance nut.

In the northern hemisphere, the direction of creep is to the right, and the balance nut must be moved IN to correct it. In the southern hemisphere creep is to the left, and the balance nut must be moved OUT. *Torpedoman's Mate 3&2,* volume 1, chapter 10, explains why. If you've forgotten that explanation, review it now.

Both of the important properties of a gyro—rigidity in space and precession—result from the effect of inertia. The law of inertia states that when any object is in motion, it will continue forever to move in a straight line, at the same speed, unless it's acted on by some outside force.

To see how this keeps a gyro rigid in space, think about the effect of inertia on a single particle in the rim of the gyro wheel. Every point on a spinning wheel is moving in a circle. Because of inertia, each particle tends to keep moving in a straight line tangent to its circular path. Molecular attraction within the wheel holds all the particles together, and keeps them moving in circles. (But of course any wheel will fly apart if you spin it fast enough.) Inertia and molecular attraction, then, tend to keep each particle in a circular path in a single plane. The gyro wheel will therefore tend to maintain its plane of rotation, and its axis will tend to maintain a fixed

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direction in space, until the system is acted on by some outside force.

The inertia of a spinning wheel, and therefore the reliability of its gyroscopic action, depends on two things: the mass of the wheel, and the speed with which it is turning. For that reason a gyroscope should be relatively heavy, and should be spun at high speed. The speed of any particle in the gyro wheel depends not only on the speed of rotation, but also on the distance of the particle from the center. That's why the weight of a gyro wheel is usually concentrated in its rim.

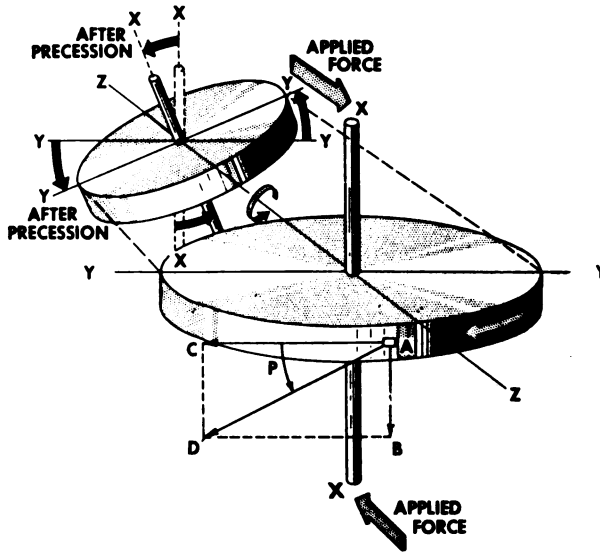

Figure 6–1.—Gyro principle.

A study of figure 6–1 will show you that gyro precession, like rigidity in space, is a result of inertia. Imagine that the larger wheel in the figure is spinning rapidly, in the direction shown by the arrow on its rim. If you now apply a force that tends to move the wheel in

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its plane of rotation, or along its axis, no precession will result because you have done nothing to change the direction of its axis. But suppose you apply a force like the one shown by the two arrows, marked "applied force", in figure 6–1. If the wheel were standing still, this force would tend to turn it about the axis Y–Y. But, because the wheel is spinning rapidly, it responds to the applied force by precessing—by moving its axis in a direction at 90° from that of the applied force.

To see why this happens, consider the forces acting on the point marked "A" in figure 6–1, at the instant represented by the figure. The inertia of the moving point A tends to carry it in the direction AC. But the force applied to the gyro axis tends to move point A in the direction AB. Assume that, in the diagram, the length of lines AC and AB are proportional to the strength of the forces acting in the direction of the lines. Because point A can't move in two directions at once, it must respond to the two forces acting on it by moving in the direction AD. (The direction and length of AD represent the vector sum of the two forces acting on point A.) In order to move in the direction AD, point A must turn the wheel's plane of rotation to the position shown in the smaller diagram of figure 6–1.

So far, we've been talking only about the single point A. But if you give it a little thought you'll see that, at the instant represented by figure 6–1, every point on the wheel (except points on the axis Y–Y) is acted on by two separate forces. For every point, the vector sum of the two forces is such as to turn the plane of rotation to the direction shown in the smaller diagram.

Precession, as you can see, moves the gyro axis in a direction at 90° from that of the applied force. Because of precession, the axis of rotation (X–X) tends to become parallel with the axis of the applied force (Y–Y). In this way a vertical force applied to the gyro axis by the balance nut can cause precession that will turn the gyro

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axis in a horizontal plane, and thus cancel its horizontal creep.

In order to serve as a reliable steering reference, the torpedo gyro must be accurately balanced. Its rotor and gimbal bearings must be as free as possible from friction, and their clearance must be accurately adjusted. There are gyros more sensitive than the torpedo gyro, but they are very delicate instruments. The torpedo gyro must be rugged enough to withstand the shock of firing and impact with the water, and to resist the effect of torpedo roll and engine vibration. Its design is therefore a compromise between sensitivity and ruggedness. Just the same, it's a precision instrument. Only the most careful maintenance can preserve the sensitivity that's built into it.

GYRO CONSTRUCTION

This section briefly reviews the construction of the Gyroscope Mk 12 Mod 3. (This is the type used in all the air-steam torpedoes, and in the Mk 18 electric torpedo.) The steering mechanism, which translates the relative gyro position into rudder movement, is described in chapter 10 of *Torpedoman's Mate 3 & 2*, volume 1.

Figure 6–2 shows the gyro and its inner gimbal ring, disassembled. The end that will be forward when the gyro is mounted in the torpedo is at the left in the picture.

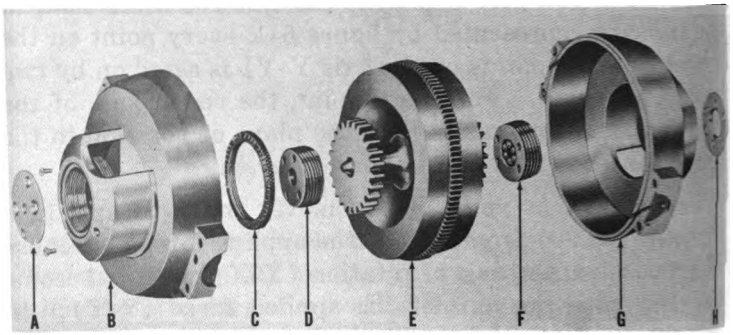

Figure 6–2.—Gyro wheel and inner gimbal ring, disassembled.

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The gyro wheel (E in fig. 6–2) is made of monel metal, and is accurately balanced on its spindle (or axis). During the torpedo run, gyro-sustaining air strikes the saw-tooth buckets machined in the outer rim of the wheel, and keeps the wheel turning at the proper speed. (These buckets are not used when the gyro is installed in a Mk 18 torpedo; after the initial spin, the gyro of a Mk 18 is allowed to coast.) A spur gear is machined on an enlarged section at each end of the gyro wheel spindle. The after spur gear engages a similar gear on the shaft of the spinning and unlocking mechanism (described in *Torpedoman's Mate 3&2,* volume 1.) After the initial spin, these gears are disengaged before the gyro is unlocked. The spur gear on the forward end of the spindle is provided to balance the weight of the after gear, and to provide equal air resistance. (A difference in either weight or air resistance would provide a force tending to turn the gyro axis, and thus cause precession.)

The gyro wheel is enclosed by a split casing called the inner gimbal ring (B and G in fig. 6–2.) Note the channels in the brackets of the after half (G). When the two halves of the ring are assembled, these channels form ducts that carry the sustaining air to the buckets on the wheel rim. The air escapes through openings at the top and bottom of each end of the inner gimbal ring, in such a direction that it does not strike the outer gimbal ring. Thus the escaping air applies no forces that might cause precession.

In the forward half of the inner gimbal ring is a sleeve with both inside and outside threads. On its outside it carries the balance nut (C in fig. 6–2). The forward wheel bearing (D) screws into the forward end of the inner gimbal, and is secured by a locking disc and screws (A); it supports the forward end of the wheel spindle. The after end of the spindle is supported by the after wheel bearing (F), which is secured in the after half of the gimbal by a second locking disc (H). A socket is machined in the after end of the after wheel bearing to

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engage the centering pin of the spinning and unlocking mechanism. When the gyro wheel is assembled in the inner gimbal, it can turn freely in its bearings, without side play or end play.

The outer gimbal ring is shown in figure 6–3. It supports the inner gimbal ring in side bearings, which are mounted in the openings shown at right and left in the figure. The figure shows one of the air passages partially cut away. A similar passage is located in the left side of the ring. Gyro-sustaining air enters through the center of the top bearings, goes through the two passages in the outer gimbal, through the side bearing sleeves, and through the ducts of the inner gimbal to the gyro wheel buckets. The outer gimbal ring is supported by two bearings: The top bearing engages a bearing race in the gyro top plate; the bottom bearing is supported in the gyro bottom head. The cam plate has a central opening; it surrounds the top bearing, and is secured to the upper surface of the outer gimbal ring.

Figure 6–3.—Outer gimbal ring, showing partial cut-away of air passage.

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Figure 6–4 shows a side view of the assembled gyro and gimbals, with the cam plate and bottom bearing in place. When the gyro assembly is mounted in the gyro pot, the end shown at the left in figure 6–4 will be forward. The gyro wheel, in its gimbals, has three degrees of freedom. That means it can turn on any of three axes, all perpendicular to each other, in any combination. The gyro wheel is free to spin, on a fore-and-aft axis, in its wheel bearings in the inner gimbal ring. The inner gimbal, in turn, is free to rotate on an athwartship axis in the side bearings of the outer gimbal ring. And the outer gimbal ring is free to turn on a vertical axis in its top and bottom bearings. Thus no

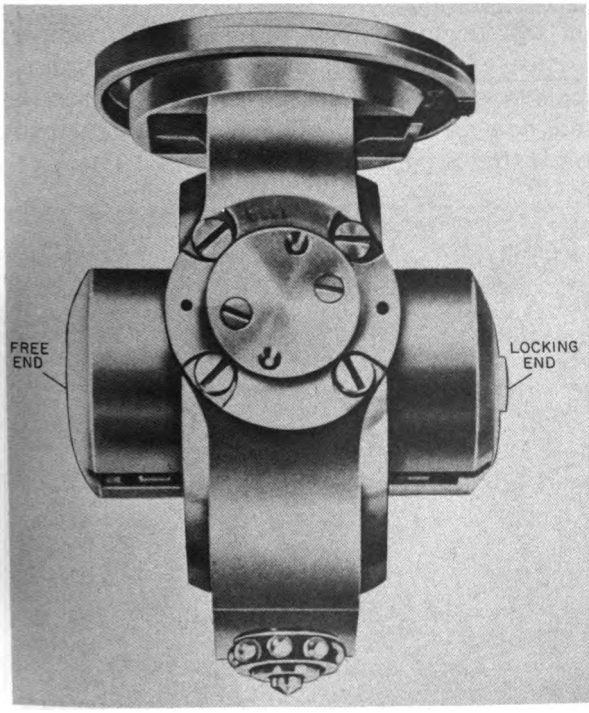

Figure 6–4.—Side view of assembled gyro and cam plate.

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combination of torpedo movements, in roll, pitch, or yaw, can change the direction of the gyro wheel axis.

Figure 6–4 will also show why a moderate amount of vertical creep has no effect on torpedo steering. Vertical creep merely turns the inner gimbal in its side bearings, with no effect on the cam plate. Horizontal creep, on the other hand, will turn the outer gimbal, which takes the cam plate along with it.

Figure 6–5 shows the parts of one of the side bearing assemblies that support the inner gimbal ring in the outer gimbal ring. Figure 6–6 shows the bottom head and bottom bearing assemblies, disassembled. In figure 6–6, the parts are: (A) Cam plate; (B) outer gimbal ring; (C) inner gimbal ring; (D) bottom gimbal center, or pivot; (E) holding screws for D; (F) inner race of the bottom bearing; (G) ball bearings and retainer; (H) outer race of bottom bearing; (I) bottom head; (J) holding screws for I; (K) keep screw (which threads into a small hole in I after M is properly adjusted); (L) cotter pin for K; (M) bottom bearing holder; (N) lock

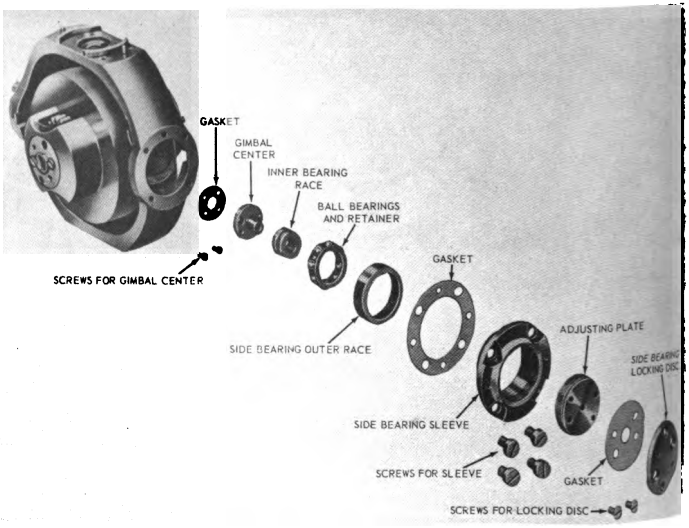

Figure 6–5.—Side bearing assembly and inner gimbal ring bearing, disassembled.

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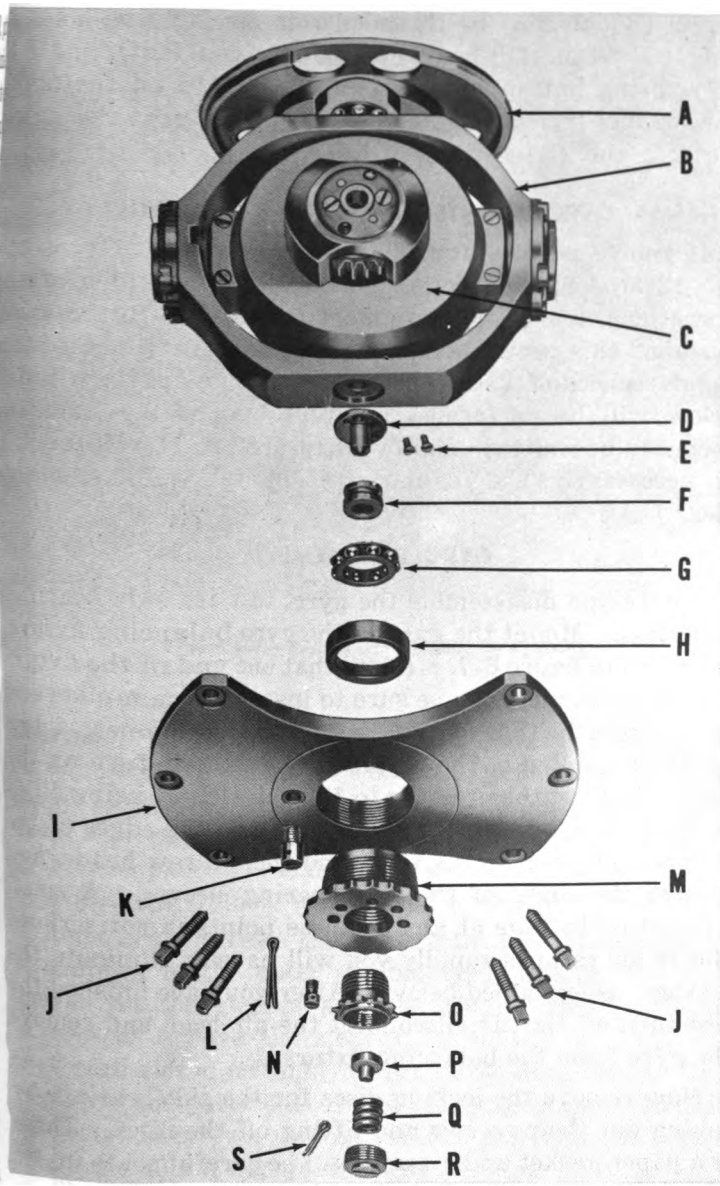

Figure 6–6.—Gyro with cam plate attached, showing bottom head assembly and bottom bearing assembly, disassembled.

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screw (which may be threaded into any of five holes in M); (O) adjusting body (which receives P, Q, and R); (P) spring button (the bottom of D seats on the upper face of P); (Q) spring; (R) plug (which provides a seat for Q); and (S) cotter pin for N.

GYRO MAINTENANCE AND OVERHAUL

If you've never watched the overhaul of a Gyroscope Mk 12 Mod 3, this section will give you an idea of the operations, tools, and equipment involved. But remember that this section is NOT to be used in place of the regular checkoff list. (Not all of the operations listed below will be performed in every overhaul. Some of them can be omitted unless your inspection shows them to be necessary. The regular checkoff list will make this clear.)

GYRO DISASSEMBLY

Before you disassemble the gyro, test its side bearings tightness. Mount the gyro in the gyro balancing fixture, as shown in figure 6–7. (Note that one end of the fixture has an air connection; be sure to insert the cam-plate end of the gyro in that end of the fixture.) Connect a low pressure air line to the nipple in the fixture, turn on the air, and adjust the pressure to 125 psi. Now, using oil as in figure 6–7, test for air leakage around the edges of the side bearing locking discs, around their screw heads, and around the edges of the side bearing sleeves. A small amount of leakage at any of these points is not serious. But if air escapes rapidly you will have to eliminate the leakage, as explained below. After you have finished the test turn off the air, disconnect the air lead, and remove the gyro from the balancing fixture.

Now remove the locking discs for the side bearings by taking out their screws and lifting off the discs. There is a paper gasket under each disc; be careful not to injure it. Inspect the sleeve threads for rust and dirt. Clean them if necessary, but don't change the position of the

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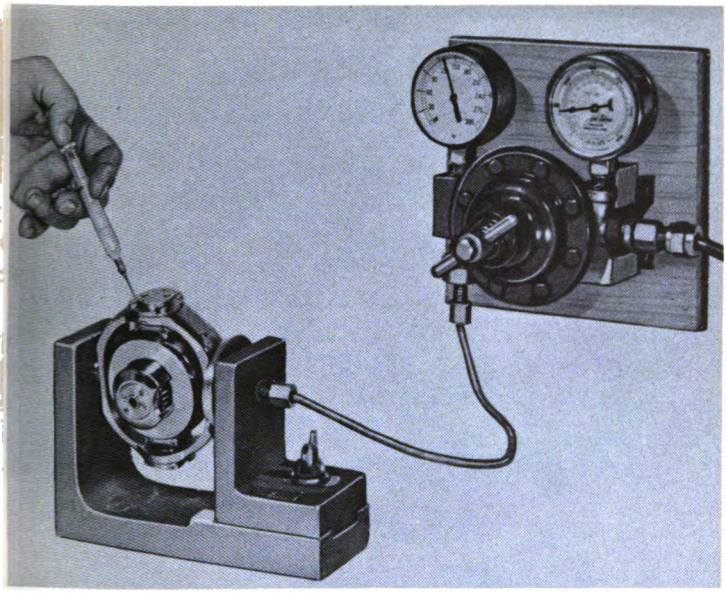

Figure 6–7.—Testing side bearings for tightness.

bearings. If, during the tightness test, air was leaking rapidly around the screw heads in the locking discs, lap these screw heads to their seats. Replace the locking discs and paper gaskets, and secure with screws. (If there was excessive leakage of air around the discs, use new gaskets; if not, use the old ones.)

Remove the screws that secure the side bearing sleeve assemblies to the outer gimbal ring, noting the bench marks on the sleeves and the ring. Use two lifting screws to remove the sleeves, as shown in figure 6–8. Put each sleeve assembly, with its holding screws, in a separate compartment of the cleaning stand. Identify the original screws, so that you can put each one back in the same hole it occupied before disassembly.

Use two hardwood sticks, preferably orange wood, to pry the side bearing balls and retainers off the inner

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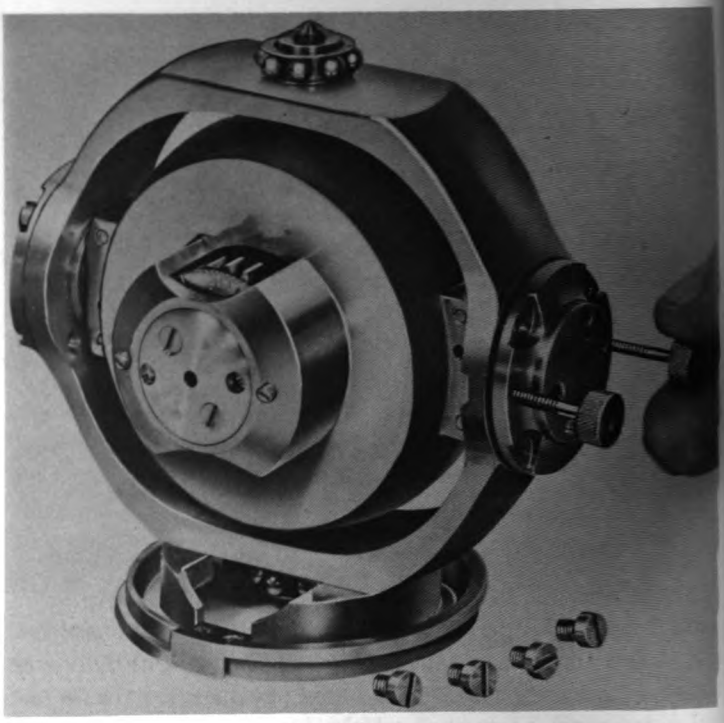

Figure 6–8.—Removing side bearing sleeves.

races. Put the balls and retainers in the proper compartment of the cleaning stand. Clamp the flanged end of tool 416 in the ball paths of the inner races, and remove them from the inner gimbal ring. Put them in their proper compartment of the cleaning stand. Now turn the inner gimbal ring into a vertical plane. Remove it from the outer gimbal ring by turning it so that its centers pass through the slots in the outer ring. (See fig. 6–9.)

The next step is to disassemble the inner gimbal ring. First, remove the screws that hold the two halves of the ring together. Scratch assembly marks on the ring and

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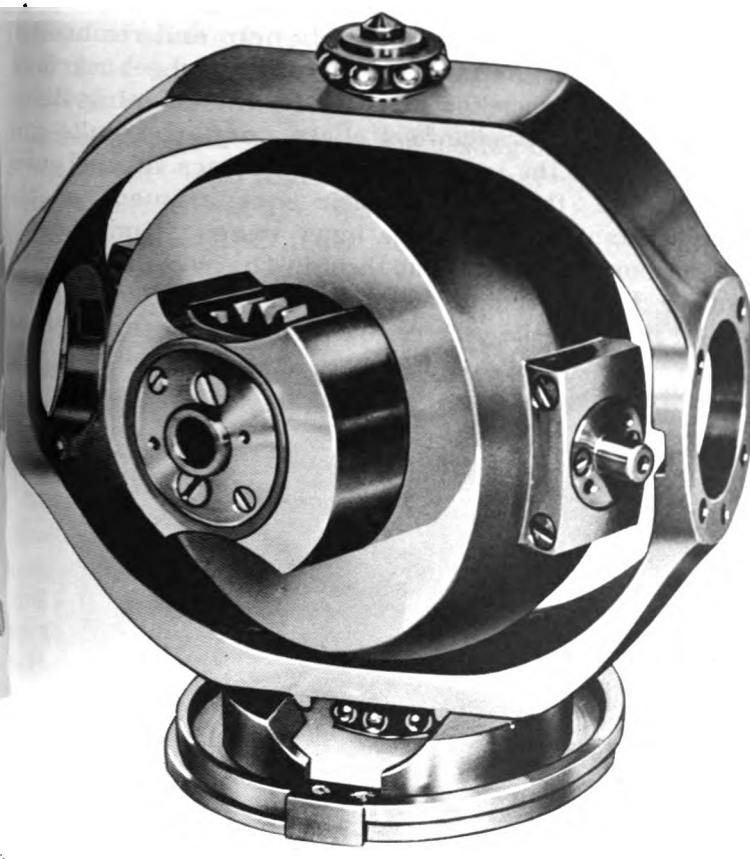

Figure 6–9.—Removing inner gimbal ring.

the flanges of its centers. Remove the holding screws from the side bearing centers. Lift off the centers and their gaskets, and put them in their proper compartment. Turn the inner gimbal ring so that the gyro spindle is vertical. Use lifting screws to start the two halves of the ring apart. As the ring parts, grasp the upper spur gear and hold it securely in the upper wheel bearing to

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keep the balls from falling out. (See fig. 6–10.) Turn the upper half over, put it on the bench, and remove the gyro wheel. Remove the balls from both wheel bearings, and put them in their compartment in the cleaning stand.

With the two orangewood sticks, pry the balls and retainers from the top and bottom centers of the outer gimbal ring. Put them in their compartment of the cleaning stand. Remove the inner races from the top and bottom centers, and put them in their compartment. Remove the holding screws for the top and bottom centers; lift off the centers and their gaskets, and put

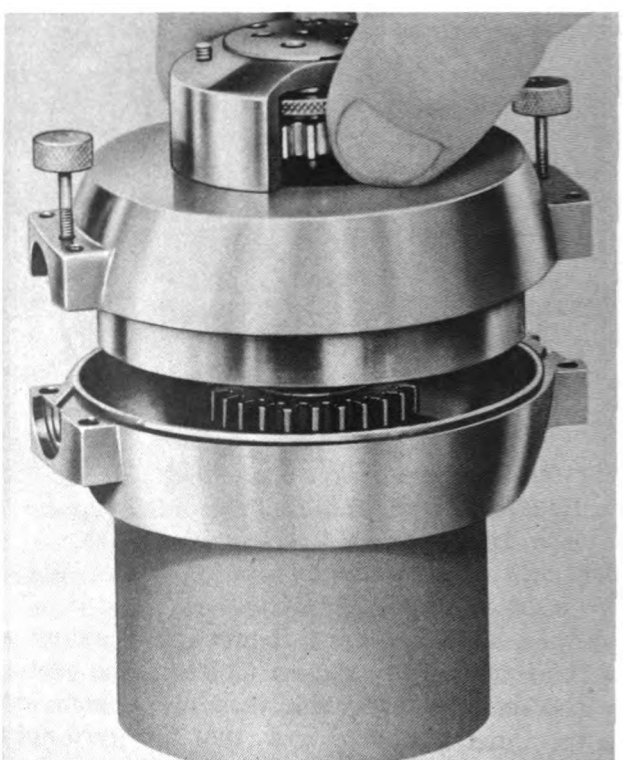

Figure 6–10.—Disassembling inner gimbal ring.

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them in their compartment. If the cam plate has been bent out of alinement, remove its holding screws and take it off the outer gimbal. (If the cam plate has not been damaged, leave it in place on the outer gimbal ring.)

Remove the screws from the locking discs of the inner gimbal wheel bearings. With the discs still engaged in their bearings, use a spanner wrench to remove the bearings from the inner gimbal. Put them in their proper compartment.

Remove the screws from the locking discs of the side bearings. With the locking discs engaged in the adjusting plates, remove the adjusting plates with a spanner wrench. Put them in their compartment. Remove the outer races from the side bearing sleeves, and put them in the proper compartment.

The next operation is to remove the bottom bearing assembly from the gyro bottom head. First back out the spring plug on the adjusting body. Remove the spring and spring button, clean and oil them, and replace them in the adjusting body. Replace the spring plug in the adjusting body, and tighten it. Next, remove the outer race from the bottom bearing holder. Remove the cotter pin from the lock screw, then remove the lock screw and adjusting body from the bottom bearing holder. Remove the cotter pin from the keep screw, then remove the keep screw and the bottom bearing holder from the bottom head.

Now remove the top bearing outer race from its holder in the gyro top plate. Do not remove the top bearing holder unless you have to. If you do remove it, make sure you save the spacing washer that's under it, and replace this washer when you reassemble.

Gyro Overhaul, Assembly, and Test

Clean, inspect, and oil the bottom bearing holder; then replace it in the bottom head. Secure it with the keep screw and cotter pin. Clean, inspect, oil, and replace the

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adjusting body; secure it with the lock screw and cotter pin. Clean the outer race of the bottom bearing, inspect it for wear and pits, oil it, and replace it in the bottom bearing holder.

Clean and inspect the top bearing holder, and make sure that the extender is not clogged or distorted. Clean and inspect the spacing washer. Oil the washer and bearing holder, replace them in the gyro top plate, and tighten. Clean the outer race of the top bearing, inspect it for wear and pits, oil it, and replace it.

Connect an air line to the nipple in the gyro top plate, and turn on the air at 125 psi. Use oil to test for leakage around the edges of the top bearing. Then turn off the air and remove the air line. If there was excessive leakage, disassemble the bearing, find the cause, and correct it.

Clean and inspect the centers and gaskets for the outer gimbal ring. Lap any of the following parts that may require it: small diameters of the centers (fig. 6–11); flats for centers on the outer gimbal ring; flat surfaces of the centers; centers to flats on the ring. Wash the parts after lapping. Put a drop of oil on each of the paper gaskets. Replace the gaskets and centers on the outer gimbal ring, and secure with holding screws.

If, during the leakage test, you found excessive leakage around the edges of the side bearing sleeves, lap the sleeves, then lap them to the outer gimbal ring. Wash the parts thoroughly after lapping. Clean, inspect, and oil the adjusting plates. Clean, inspect, and oil the gaskets and locking discs, and assemble them to the adjusting plates. Screw the adjusting plates into the sleeves, and secure them with holding screws. Clean the outer races, inspect them for wear and pits, oil them, and replace them in the side bearing sleeves.

Now test the top center of the outer gimbal ring for leakage. First blank off the air to the side bearing by installing the gyro blanking tool (SG9046). Now install

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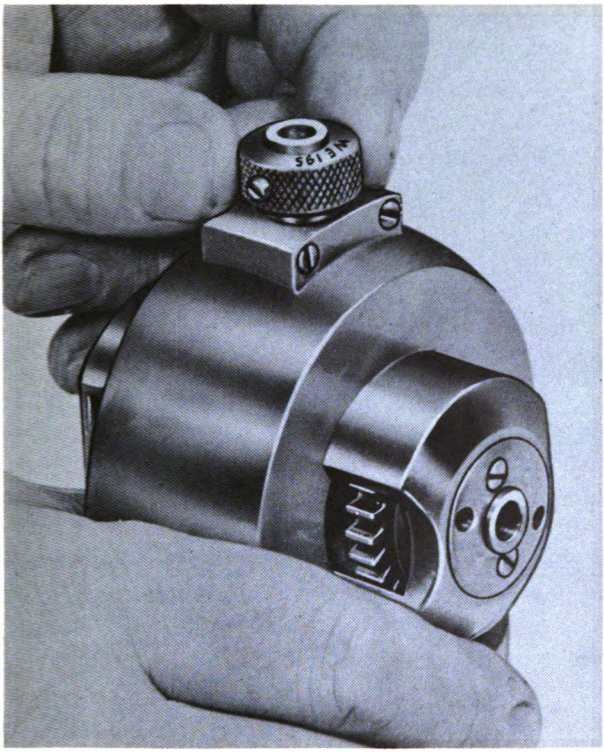

Figure 6–11.—Lapping gimbal centers.

the test nozzle in the top center, and admit air until the pressure in the gimbal ring reaches 90 psi. Use oil to test for leakage around the edges, around the holding screws, and over the lifting holes of the top center. Turn off the air; remove the test nozzle and the gyro blanking tool. If you found excessive leakage around the centers, remove them and lap them to the outer gimbal ring. Lap the screw heads into the centers. Replace the centers and repeat the leakage test.

Clean and inspect the wheel bearings for the inner gimbal ring. If necessary, lap the bearing races and the

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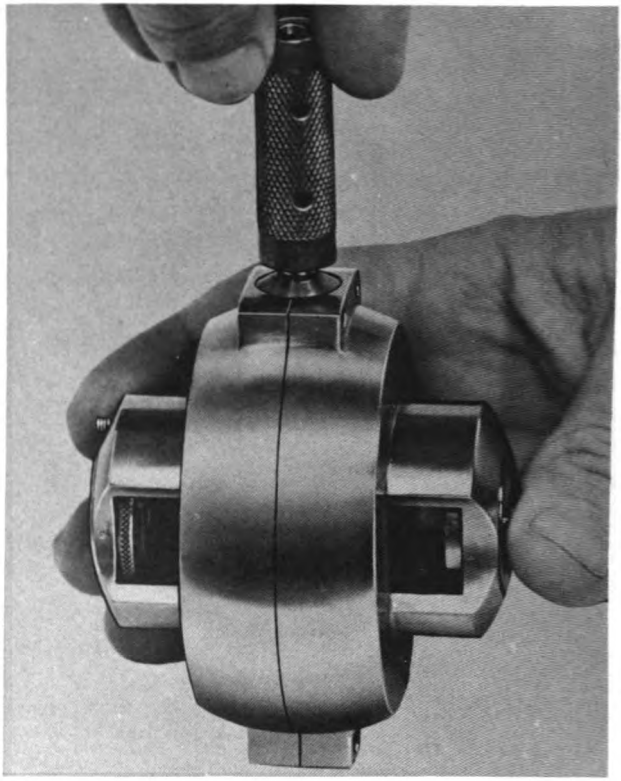

Figure 6–12.—Lapping seat for pivot in center gimbal.

wheel bearing threads; wash after lapping. If you have to install a new wheel bearing, use the most accurate scales available to make sure it weighs exactly the same as the old one. You can use the gyro-bearing polishing machine to remove excess weight from the new bearing.

Clean and inspect the centers for the inner gimbal ring. If necessary, lap the small diameters of the centers, lap the flat surfaces of the centers, lap the flats on the inner gimbal ring, and lap the centers to the flats. Wash after lapping.

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Clean and inspect the two halves of the inner gimbal ring, with special attention to the joint. If there are burrs on the joining surfaces, stone them off. Clean, inspect, and oil the inner gimbal ring wheel bearings, and assemble the locking discs in the two halves of the inner gimbal ring, and screw the bearings in. Replace and tighten the screws for the locking discs.

Clean and inspect the inner races for the inner and outer gimbal ring centers. If necessary, lap the holes in the inner races.

Clean and inspect the gyro wheel, and make sure that its pivots are free from rust, pits, and dents. If the pivots are dented, install a new gyro wheel and send the old one to the Naval Torpedo Station, Newport, for overhaul. Clean the ring of the gyro centering fixture, and set the gyro wheel on the ring. With a dial indicator, measure the height of the wheel pivot, as in figure 6–13. Then turn the gyro wheel over and measure the height of the other pivot. The difference in the two readings should be 0.0005 inch or less; if it's more than that, stone the high pivot and repeat the measurement. Repeat until you bring the two readings within the required tolerance.

Clean and inspect the balls of the gyro wheel bearings, and measure their diameters. The balls must be of the same diameter, and free from rust, pits, and flat spots. Put the balls in their races in the wheel bearings. Turn each ball with a scribe to check for freedom of movement. With a needle syringe, put two drops of oil on the balls of each bearing. Place the gyro wheel in one of the bearings. Turn the wheel and gimbal half over, holding the wheel in the bearing by its spur gear, to keep the balls from falling out. See that the bench marks on the wheel coincide with the bench mark on the gimbal. Fit the gimbal halves together and secure them with holding screws. Replace the paper gaskets for the inner gimbal ring centers, and put one drop of oil on each gasket.

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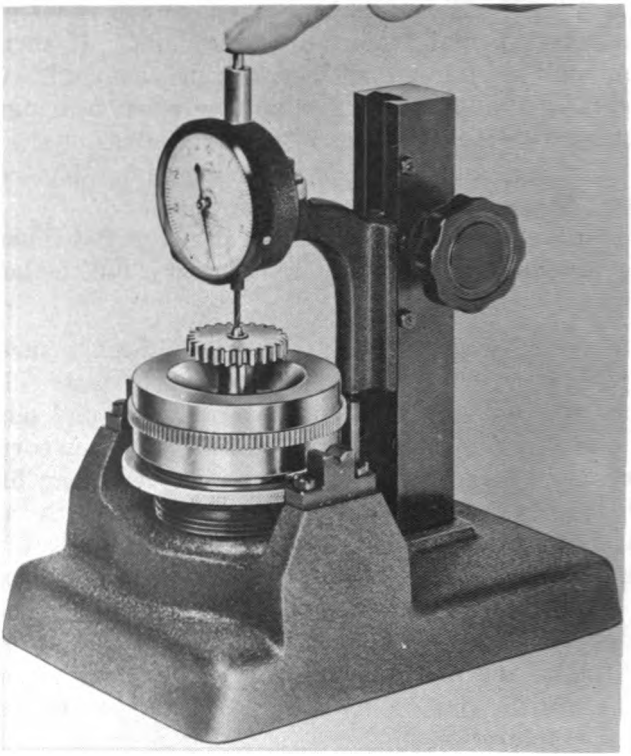

Figure 6–13.—Measuring height of pivot in wheel.

Replace the centers; make sure the scribe marks on the centers coincide with those on the gimbal ring; then secure the centers with their holding screws.

Set the balance nut for static balance (one and a half turns in from the hard-up position against the end bearing boss). Set the inner gimbal ring in the gyro centering fixture, with its centers resting in the V–blocks. Raise the adjustable ring of the fixture until it barely touches the lower gimbal half, but does not lift the centers off the V–blocks. Lower the point of the dial indicator through the locking disc (fig. 6–14), and when

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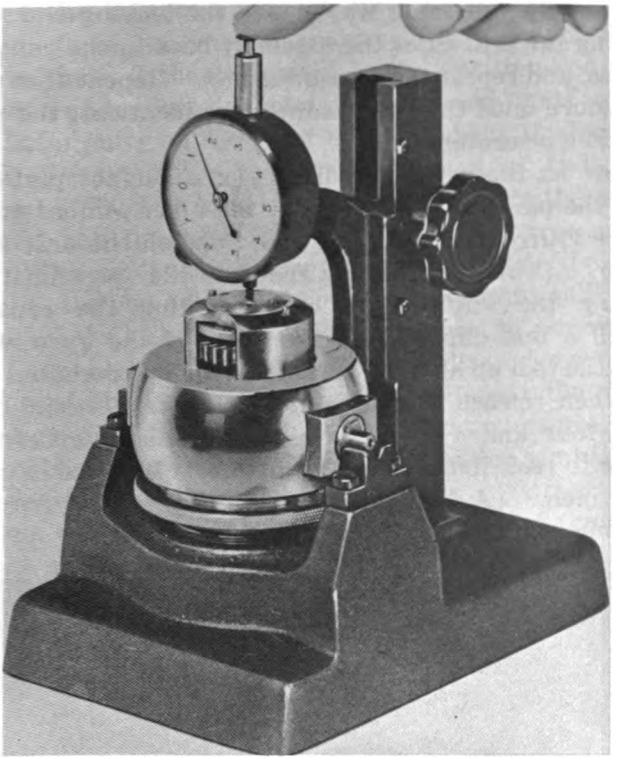

Figure 6–14.—Centering wheel in inner gimbal.

it touches the gyro wheel pivot set the indicator reading to exactly zero. Reverse the inner gimbal ring in the fixture, take a reading on the other pivot, and record this reading.

If there's any difference in the two readings, the gyro wheel is off center. Let's say, for example, that the dial indicator reading is greater on the locking end. That means you'll have to move the locking-end bearing toward the center, and move the other one away from the center. Scribe a pencil line on the free-end locking disc and the inner gimbal ring. Loosen the screws, move the free-end bearing outward a short distance, and then tighten the

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screws. In the same way, move the locking-end wheel bearing inward. Put the assembly back in the centering fixture, and repeat the measurements. Repeat this whole procedure until the two readings are identical; the wheel will then be centered.

Now set the knife edge fixture on a surface plate, and level the plate both ways. Put the inner gimbal centers on the knife edges near one end, and roll the unit to the center. (This procedure reduces the possibility of nicking the knife edges or scratching the centers.) Install a test clip on the spur gear of the gyro wheel. Hold the tool up against the side of the inner gimbal ring, and then release it (fig. 6–15). The tool should make from four and a half to five full oscillations before it comes to rest, indicating a gyro wheel clearance of about 0.001 inch. (A full oscillation is a swing away from the starting point, plus a swing back toward it.)

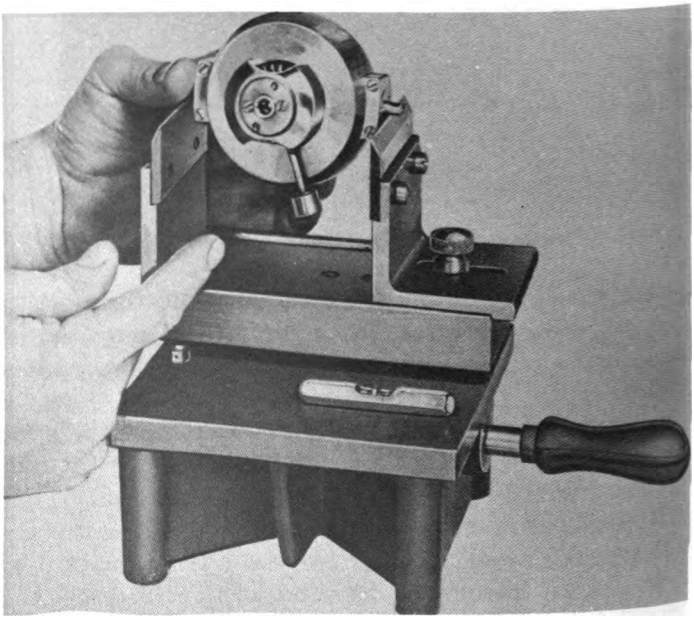

Figure 6–15.—Testing gyro wheel in bearings.

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Check the balance nut to be sure it's one and a half turns in from its hard-up position. If the gyro is in static balance, it should remain in any position you turn it to, with no tendency to rotate. If one end tends to fall, put a little putty on the other end and check the balance again. Keep adding putty until the two ends are balanced. Then remove the locking disc from the heavy end, and rub its outer face with medium-coarse emery cloth. The amount of putty you had to add to the light end will give you an idea of how much weight you'll have to take off the locking disc. Be careful not to remove too much weight. Replace the locking disc, remove the putty, and check the balance again. Repeat the whole procedure until you reach the point of static balance.

Replace the inner gimbal ring in the outer gimbal ring by reversing the disassembly procedure. With a needle syringe, put two drops of oil on each center of the inner gimbal ring. Replace the inner races on the inner

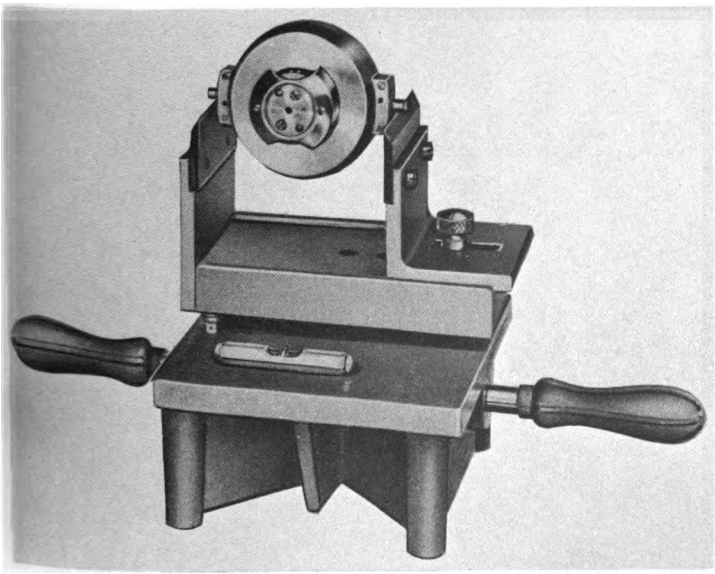

Figure 6–16.—Testing inner gimbal for static balance.

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gimbal ring centers, with the manufacturer's markings on the outboard end. Force the races all the way on. Clean, inspect, oil, and replace the balls and retainers on the inner races. Replace the paper gaskets (with one drop of oil on each), sleeve assemblies, and locking discs, and secure with screws. Clean, inspect, oil, and replace the inner races, balls, and retainers on the top and bottom centers of the outer gimbal ring.

Now install the gyro assembly in the gyro balancing fixture; tighten the movable end of the fixture with just enough clearance between bearings to let the gyro rotate freely. Loosen the locking disc screws of each side bearing assembly. Turn each side bearing clockwise until it's just hand-tight, then tighten the screws for the locking discs. Hold one side of the outer gimbal ring a little below the level of the other, and let it fall. Notice how fast it falls. Do the same with the other side. If

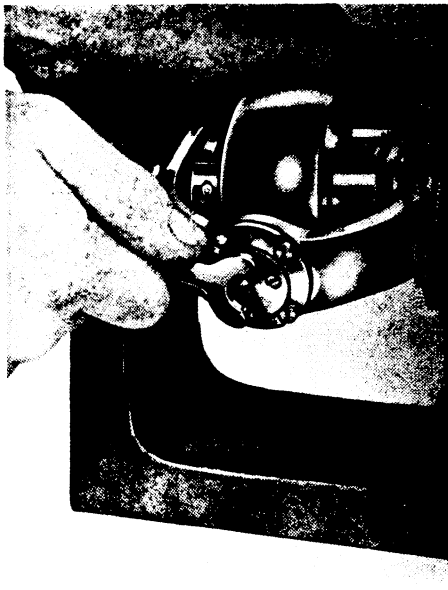

Figure 6–17.—Centering inner gimbal ring in outer gimbal.

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one side falls faster than the other, that side is heavier. Scribe a line on both locking discs and gimbal. Loosen the holding screws. Move the side bearing (locking disc) away from the center on the light side, and the same amount toward the center on the heavy side. (See fig. 6–17.) Then tighten the holding screws. Repeat the test and adjustment until both sides fall at the same rate. The inner gimbal ring will then be centered in the outer gimbal ring.

Scribe pencil lines on the side bearing locking discs and the gimbal. Turn both side bearings (locking discs) counterclockwise a short distance. Be sure to turn the two bearings an equal distance; the pencil lines will enable you to judge this accurately. Tighten the holding screws. Using a jack tool, bring both outer bearing races up against the adjusting plates, as in figure 6–18.

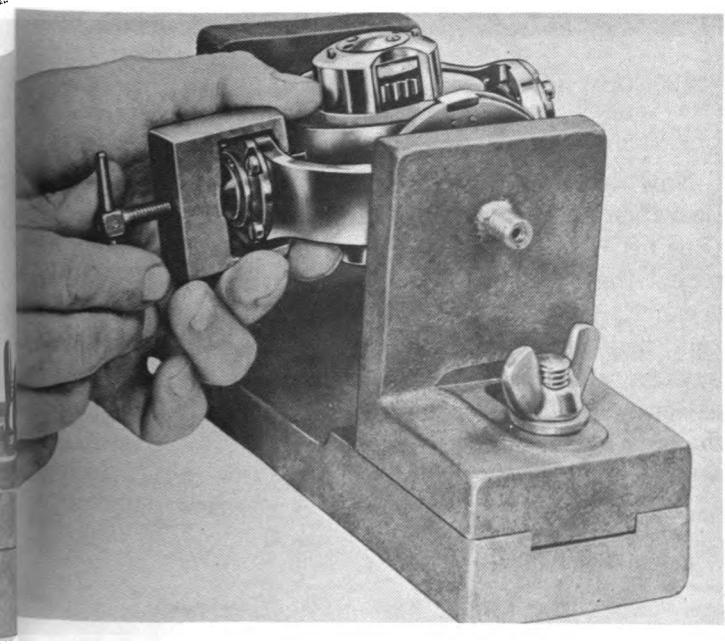

Figure 6–18.—Positioning outer bearing races against adjusting plate.

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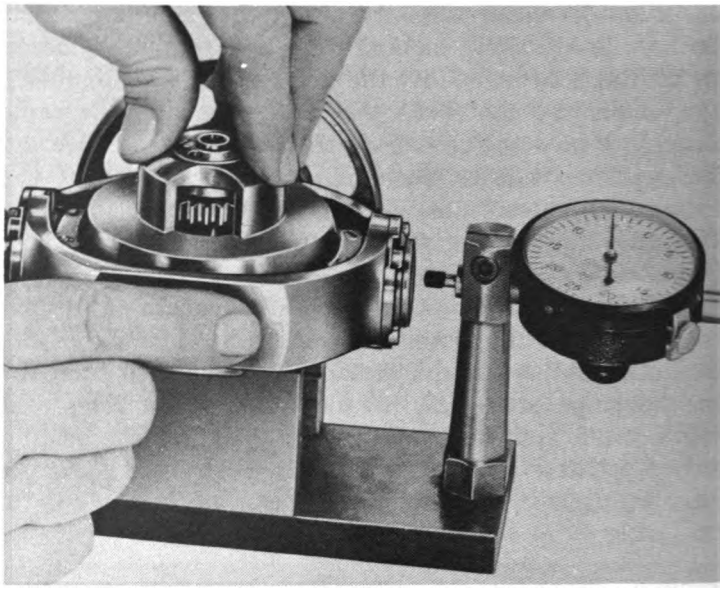

Figure 6–19.—Checking side bearing clearance.

Now set the gyro assembly on the side bearing clearance testing fixture, and measure the clearance. (See fig. 6–19.) If the clearance is less than 0.005 inch, repeat the procedure described above until the clearance is exactly 0.005 inch. If the clearance is more than 0.005 inch, use the same procedure but turn the two bearings inward. Be sure to turn both bearings the same amount.

Return the gyro to the gyro balancing fixture, and test the side bearings for leakage.

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QUIZ

1. What are the two basic properties of a gyro?
2. Both of these properties are effects of the same force. What is this force called?
3. Why is a fixed direction on the earth not necessarily a fixed direction in space?
4. Give a practical definition of the expression "a fixed direction in space."
5. If you fire a torpedo (anywhere on earth) with its gyro axis pointed at the north star, in what direction will the gyro creep?
6. Gyro creep can be considered as made up of two separate components. What are they?
7. Which component of creep has a significant effect on torpedo steering?
8. In the northern hemisphere, in which direction does the gyro creep, and in which direction must you move the balance nut to compensate for creep?
9. When a gyro undergoes precession, in what direction does its axis move, with respect to the direction of the applied force?
10. Explain briefly why the balance nut can be used to compensate for horizontal creep.
11. Which gyro is used in air-steam torpedoes and in the Mk 18 electric torpedo?
12. What is the principal difference between the two wheel bearings that support the gyro spindle?
13. What is the purpose of the spur gear on the after end of the gyro spindle?
14. What is the purpose of the spur gear on the forward end of the gyro spindle?
15. What is meant by "three degrees of freedom" in a gyro?
16. Which part or parts of the gyro assembly can turn on a vertical axis? On an athwartship axis? On a fore-and-aft axis?
17. Trace the flow of low-pressure air through the gyro and gimbal assembly.
18. Explain briefly why the steering mechanism can detect only the horizontal component of gyro creep.

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CHAPTER 7

CONTACT TORPEDO EXPLODERS

If you need to review the basic principles of exploder operation see *Torpedoman's Mate 3&2,* NavPers 10155. The actual marks and mods of exploders described in the 1955 edition of that course are obsolescent. A number of them remain in the fleet at the time this book goes to press, but the torpedoes that contain them are being expended. There are three types of contact exploders now current. These are the Mk 6 Mod 13, the Mk 11 Mod 2, and the Mk 14 Mod 2. These three exploders are described in this chapter.

The newest homing torpedoes are provided with influence exploders, which will be discussed in volume 2 of this course.

TORPEDO EXPLODER MK 6 MOD 13

The Mk 6 Mod 13 is a contact exploder mounted on a rectangular base plate. It fits in the lower side of the forward end of war heads for torpedoes Mk 14, Mk 15, Mk 16, and Mk 23 types. The lower surface of the base plate is formed to complete the ogival shape of the war head. The exploder is armed both mechanically and electrically by an impeller and gear train. It fires electrically through an inertia-ball switch. Electric energy for firing is provided by a generator, which is driven by the impeller shaft.

Exploder Mk 6 Mod 13 is similar to the Mk 6 Mod 10,

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which is described in *Torpedoman's Mate 3&2,* NavPers 10155. For that reason the following discussion will give you only a short review of the operating principles. We'll go into detail only on those points in which the Mod 13 differs from the Mod 10. Figure 7–1 is a view of the Exploder Mk 6 Mod 13, looking from the starboard side. Like the Mod 10, the Mod 13 still has a pickup coil. This, as you may remember, is a holdover from one of the early mods of the Mk 6, which had an influence feature. The coil is retained simply to preserve the balance, trim, and pull-around characteristics of the early mods. And on many of the Mod 13 exploders you'll find that it isn't even a real coil, but just a steel or brass dummy of the same weight as the original coil.

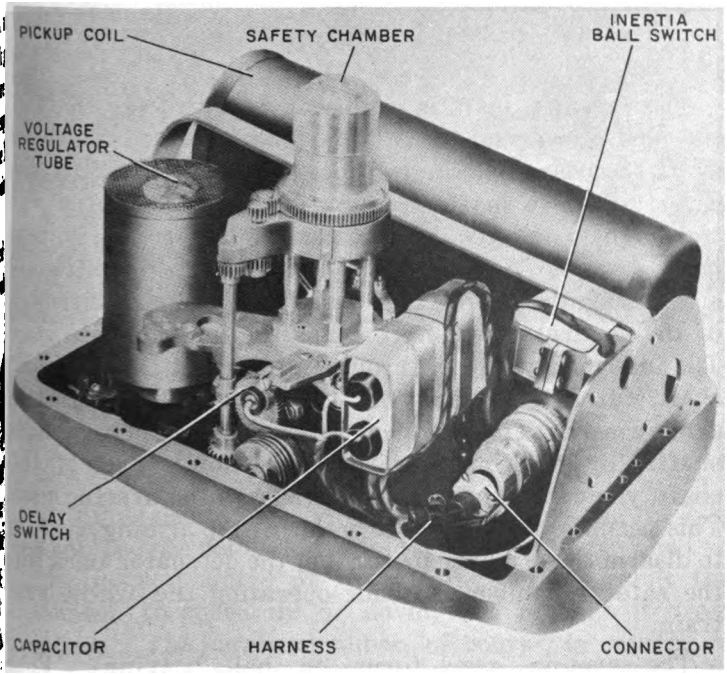

Figure 7–1.—Exploder Mk 6 Mod 13 with inertia-ball switch assembly.

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In figure 7–1 you can see two of the ways in which the Mk 6 Mod 13 exploder differs from the Mod 10. First, the Mod 13 has a plug-in type cable connector in place of the wax-filled junction box. Second, the solenoid, which was retained in the Mod 10, is not present in the Mod 13. (It has been replaced by a resistor.)

Review of Operating Principles

Figure 7–2 shows a cutaway view of the firing mechanism of a Mk 6 Mod 13 exploder. The impeller is of the usual type; it has 15 blades, and turns on an athwartship shaft. The impeller channel, through which water reaches the impeller blades, is in the port side of the base plate. In figure 7–2 you can see a part of the impeller cavity, and the stuffing box through which the impeller shaft passes, in the lower right corner of the picture.

The impeller shaft is coupled directly to the shaft of the generator armature. The armature shaft is extended at its starboard end, and carries a worm gear that turns a vertical drive shaft through a worm wheel. A second worm gear, secured to the vertical drive shaft about halfway up, drives a worm wheel that operates the electric delay device. The drive gear, secured to the top of the vertical drive shaft, turns the intermediate gear. The intermediate gear, through a pinion at the top of its shaft, turns the idler gear; the idler meshes with the arming gear. The idler gear is secured to a spring-loaded shaft. By pressing upward on the lower end of this shaft, you can disengage the idler from the arming gear. This permits you to test the action of the arming gear, or to disarm the exploder by turning the detonator back into the safety chamber, without operating the whole gear train.

The arming gear turns on ball bearings. Four retainer lugs fit in a groove at the bottom of the arming gear. These lugs hold the gear firmly in place, yet permit

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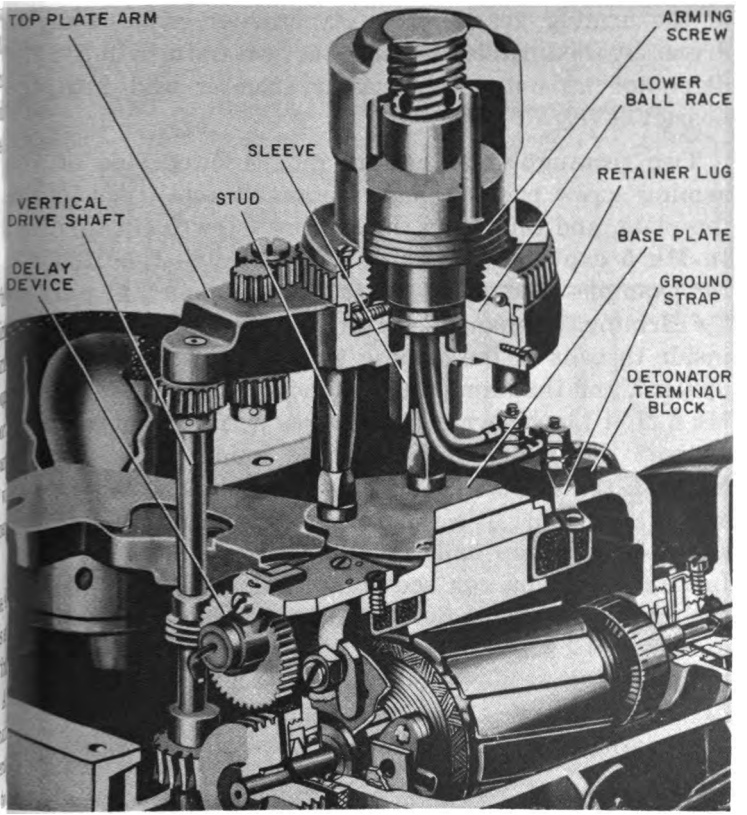

Figure 7–2.—Cutaway of firing mechanism assembly.

it to turn freely. At the top of the picture, figure 7–2, you can see the detonator in its safety chamber. The two guide posts mounted on the arming screw permit the detonator to move up or down, but prevent it from rotating. The safety chamber, of course, is secured to the arming gear by screws, and turns with the gear. Inside threads at the top of the safety chamber mate with the threads of the detonator holder. Thus the rotation

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of the arming gear and safety chamber, when they're driven by the impeller through the gear train, will lift the detonator up out of the safety chamber and into the booster cavity.

Two rectangular extensions on the lower side of the arming screw pass through rectangular openings in the top plate, and thus keep the arming screw from turning. In Mk 6 exploders that fire mechanically—the Mod 12, for example—the arming screw is an important part of the arming mechanism. During the torpedo run, the inside threads of the arming gear lift the arming screw upward, and thus compress the firing spring. But in the Mk 6 Mod 13, the arming screw has no function except to support the detonator holder and guide posts. In the Mod 13, therefore, the arming screw is ALWAYS in the ARMED position. It's secured in that position by four spring-loaded stop balls that engage an annular groove. In figure 7–2 you can see one of the stop balls, and its spring and screw, at the left side of the cutaway section of the lower ball race.

Electric Circuit

Figure 7–3 is a diagram that shows both the electric and mechanical features of Exploder Mk 6 Mod 13. During the first part of the torpedo run, the generator field circuit is grounded through the delay switch. The generator therefore has no output, and can not supply any current to the firing circuit. At the end of the arming run, the delay switch has turned until the shorting contact reaches a cutaway portion of the disc. The generator field circuit is then no longer grounded, and the generator can develop an output voltage. At the same time, a blank sector in the delay switch worm wheel reaches the worm gear on the vertical drive shaft. The delay switch will then turn no farther.

As soon as the generator develops an output voltage, it begins to charge the 8–microfarad capacitor through the

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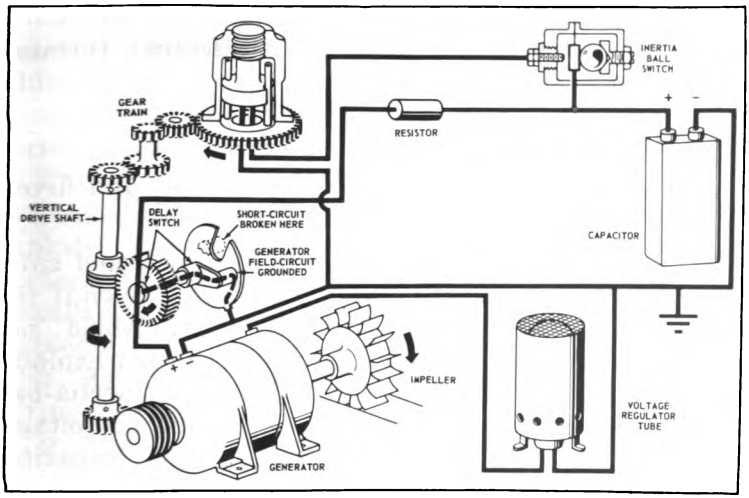

Figure 7–3.—Schematic diagram of mechanical and electrical features.

resistor. The resistor is included in the circuit to limit the current in both directions. It keeps the capacitor from drawing excessive current when it begins to charge. And, if the generator voltage should drop momentarily, the resistor will keep the capacitor from discharging rapidly through the generator windings.

As the generator speed increases, its output voltage increases. When this voltage gets high enough, it will ionize the gas in the voltage regulator tube. Current will then flow through the tube, and through an opposed-field winding in the generator. The higher the generator output voltage, the more current will flow through the opposed-field circuit. This current weakens the total field strength of the generator, and cuts the output voltage down again. This self-regulating feature will keep the generator output voltage nearly constant, even if the armature speed changes considerably.

The two leads of the electric detonator are connected to the two terminals of the capacitor; but this circuit is broken by the inertia-ball switch, which is normally open.

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On impact with the target, the inertia switch will close the firing circuit. The capacitor will discharge through the detonator, and fire it.

Arming and Firing Action

You are already familiar with the arming and firing sequence. We'll run through it very briefly.

Before launching, the exploder is disarmed and safe. The detonator is inside the safety chamber. Even if the detonator should explode accidentally, it would not initiate the booster. But the detonator can not explode, because its electric circuit is safe. The inertia-ball switch is open. The generator is developing no voltage, and the capacitor has no charge. The capacitor terminals, as well as the generator output, are shorted out by the delay switch.

When the torpedo begins its arming run, the impeller begins to turn. Through the gear train, it turns the arming gear and safety chamber, and lifts the detonator out of the chamber. After the torpedo has traveled 400 to 450 yards, the arming action is complete. The detonator has been lifted into the booster chamber. The delay switch has opened, allowing the generator to develop an output voltage and charge the capacitor. When the torpedo strikes its target, the inertia-ball switch closes and completes the firing circuit. The capacitor discharges through the electric detonator, and fires it. The detonator initiates the booster, which in turn initiates the main charge in the torpedo war head.

Repairs and Overhaul

An Exploder Mk 6 Mod 13 that requires overhaul, or an extensive replacement of parts, should be returned to the tender for forwarding to one of these places: U. S. Naval Underwater Ordnance Station, Newport; U. S. Naval Mine Depot, Yorktown; U. S. Naval Torpedo Station, Keyport.

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The stuffing box components should be removed, and the "O" rings replaced, at least once every two years. This should be done by a tender or a Fleet Shore Activity. Tenders and Fleet Shore Activities may also perform a series of tests on the exploder, following the checkoff lists in Part 6 of OP 1830, First Revision.

Aboard firing ships, no work should be done on the exploder except to install it in the war head, and to perform the test and maintenance steps associated with installation. This is the procedure for installing an Exploder Mk 6 Mod 13 in a war head:

1. Remove the exploder from its storage box, using lifting screws MF–2.

2. Blow out the mechanism with low-pressure air.

3. Remove the cover of the inertia-ball switch, and check the clearance between its contacts (tool No. 488). Clearance must be between 0.065 and 0.061 inch. Replace the cover.

4. Apply grease (E) to the inboard and outboard bearings of the exploder, using a grease gun and adapter (tools Nos. MF–1 and MF–1A).

5. Turn the exploder on its side. Remove the six screws that secure the impeller guard, and take the guard off the base.

6. Turn the impeller by hand, toward the after end of the exploder base, through several complete revolutions.

7. Apply the tip of the impeller test tool (MF–7) to the tip of one of the impeller blades. (Hold the tool so that its blade is in a plane passing through the axis of the impeller shaft.) Push the tool aft, and note the reading when the impeller begins to move. It should be not less than 20 ounces, and not more than 24. If it is not within those limits, adjust the gland nut and repeat the test. Then replace the impeller guard and its six screws.

8. Remove the holding pin from the delay device. Set the delay worm wheel to its starting position, and replace the holding pin. Check to see that the contact

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button touches the worm wheel. Make sure that the wire to the delay device is long enough to permit full engagement of the worm wheel and worm.

9. Check to see that the arming screw is in the fully armed position, with its threads free from the arming gear.

10. Detonator Mk 9 Mod 4 is shipped already assembled in its safety chamber. Check it to see that the top of the detonator holder is flush with the top of the safety chamber, and that the scribe marks on the two parts are in line.

11. Remove the four screws from the top of the arming gear (tool No. 41).

12. Slip the detonator wires through the hole in the arming screw and the top plate. Push the safety chamber into place, fitting the holes in the detonator holder over the guide posts of the arming screw.

13. Secure the safety chamber on the arming gear with four screws (tool No. 41).

14. Remove two nuts from the detonator terminals (tool No. G–41–W–2877–126).

15. Separate the two detonator leads, and connect them to the detonator terminals. (You may connect either lead to either terminal.) Secure the leads with the two nuts. Make sure the leads are not tangled, so that the detonator holder will be free to rise out of the safety chamber.

16. Coat the terminals with moisture-proofing compound (AN–C–128). This compound is furnished with the exploder, in its storage box.

17. Remove the booster (Mk 5 Mod 0, or Mk 2 Mod 0) from its container. Replace the container in its stowage place.

18. Install the booster in the booster cavity of the war head. Make sure the detonator cavity in the booster is facing outward. Check to see that the booster fits loosely, so that it will rest on the top of the safety

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chamber when the exploder is installed and the war head turned right-side-up.

19. Put the exploder base gasket on the war head flange, and install the guide screws to hold it in place.

20. Remove the lifting screws from the exploder base. Turn the exploder on its side, and install lifting screws on the outside of the base plate.

21. With the exploder cavity of the torpedo facing upward, lift the exploder onto the war head. Rest it on its side, in the proper position for installation.

22. Remove the two nuts from the terminals of the inertia-ball switch. Thread the leads from the exploder mechanism over the top of the switch, and through its base. Connect the leads to the switch terminals, and secure them with the nuts.

23. Coat the switch terminals with moisture-proofing compound (AN–C–128).

24. Tie the switch leads to the capacitor, using nylon cord.

25. Install the inertia-ball switch assembly on the exploder. (War heads are of two types. In one, the switch assembly is secured by screws to four tapped holes in the exploder casing. In the other, the forward plate of the switch assembly fits against the inner forward wall of the exploder casing, where it's centered by two lugs that fit under the casing flange; the end of the bracket strap is then fitted under the after end of the flange.)

26. Carefully slide the mechanism into place over the guide screws. Be sure the mechanism enters the cavity without binding. Don't let any part of the mechanism jam against the casing. Above all, make sure that none of the electric leads are cut, kinked, jammed, or disconnected.

27. Remove the guide screws. Insert the holding screws and set them up evenly (tools Nos. 41, 49).

To test for leakage, follow the instructions for leakage test of Exploder Mk 14 given later in this chapter.

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TORPEDO EXPLODER MK 11 MOD 2

The Mk 11 Mod 2 is a contact exploder used in Torpedo Mk 27 Mod 4. An impeller and gear train arm the exploder both mechanically and electrically. It fires electrically through an inertia-ball switch. Figure 7–4 shows an overall view of the exploder. Unlike most of the exploders you're familiar with, the Mk 11 mod 2 is mounted in the nose of the torpedo, as shown in figure 7–5. The 24-volt electric current that fires the primers

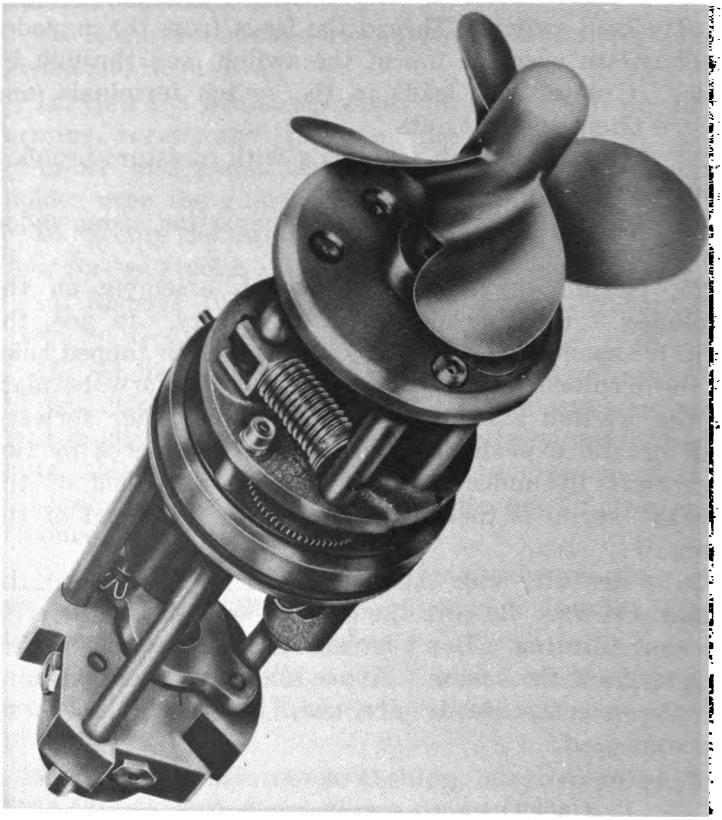

Figure 7–4.—Torpedo Exploder Mk 11 Mod 2.

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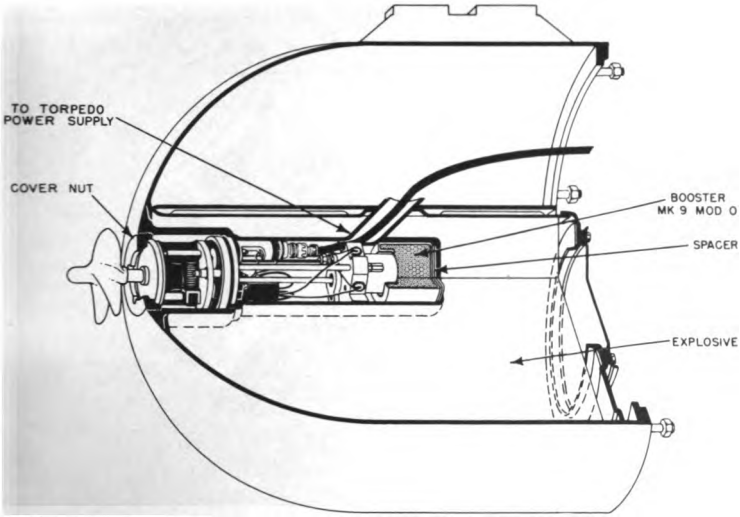

Figure 7–5.—Torpedo Exploder Mk 11 Mod 2 installed in torpedo war head.

is provided by the torpedo power supply, through a connecting cable.

Figure 7–6 shows the three principal sections of the Mk 11 Mod 2 exploder. The impeller seats on the spring-loaded impeller plunger shown at the top of the picture; it's held in place by a locking plate, as we'll explain later. Just to the left of the impeller plunger in figure 7–6, you can see the arming distance dial. On this dial are the markings 100, 200, 300, and S (SAFE). The three numbers refer to the length of the arming run, in yards. But the 100- and 200-yard settings have been inactivated, leaving you a choice of only two settings: 300 yards, and SAFE.

The impact section includes the inertia firing switch, the connector to which you attach the cable from the torpedo power supply, two distance switches that arm the torpedo electrically after 300 yards of travel, and the detonator shutter shaft. The shorting bar, represented

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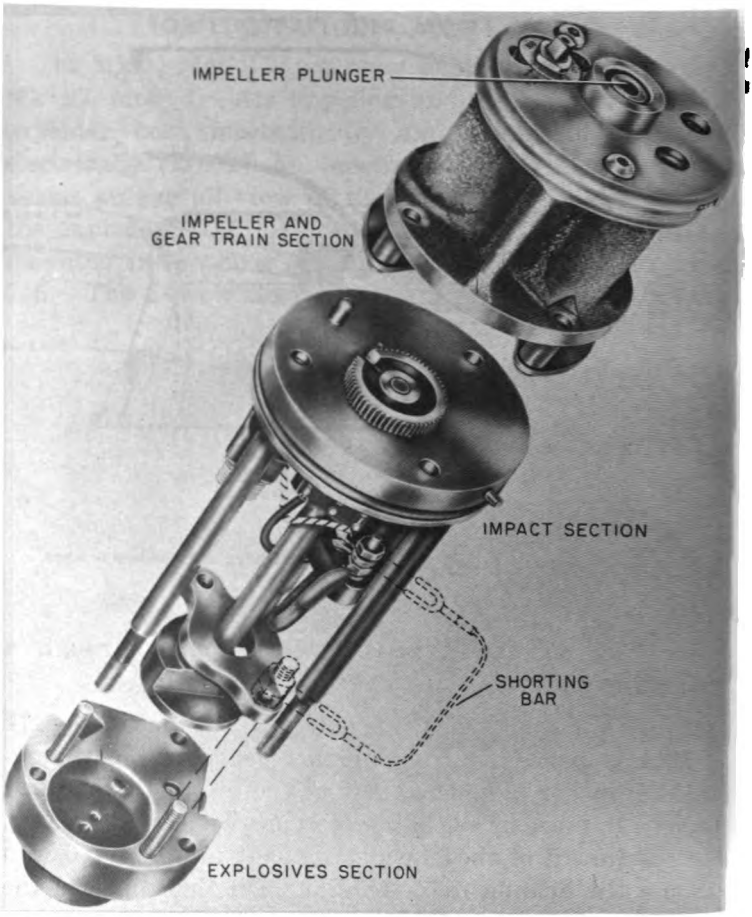

Figure 7–6.—Major sections of exploder.

by dotted lines in the picture, is in place at all times during shipping, stowage, and handling. It shorts the two electric primers to ground, so that no current can pass through them accidentally. You remove the shorting bar just before you install the exploder in the torpedo.

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The explosives section contains the entire explosive train (except, of course, the main charge). This train consists of two electrically fired primers, two detonators, a booster lead-in, and the booster.

Gear Train

Figure 7–7 is a closer view of the impeller and gear train section; figure 7–8 is a diagram of the gear train. Refer to both these pictures as you read the following discussion.

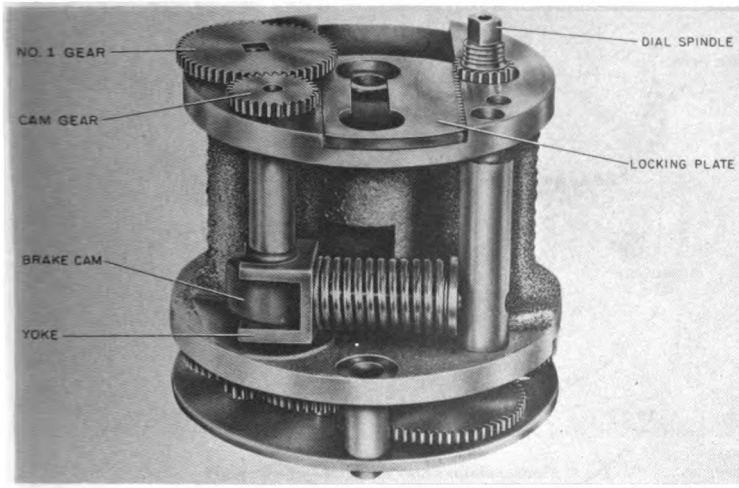

Figure 7–7.—Impeller and gear train section.

First of all, find the locking plate in the illustrations, and note the slot that runs parallel to its long dimension. At each end of this slot is a circular opening. The function of the locking plate is simply to secure the impeller in place. When the arming distance dial is set on SAFE, one of the two circular openings is in line with the impeller plunger. This makes it possible to insert the impeller (fig. 7–9) in the exploder. The retainer

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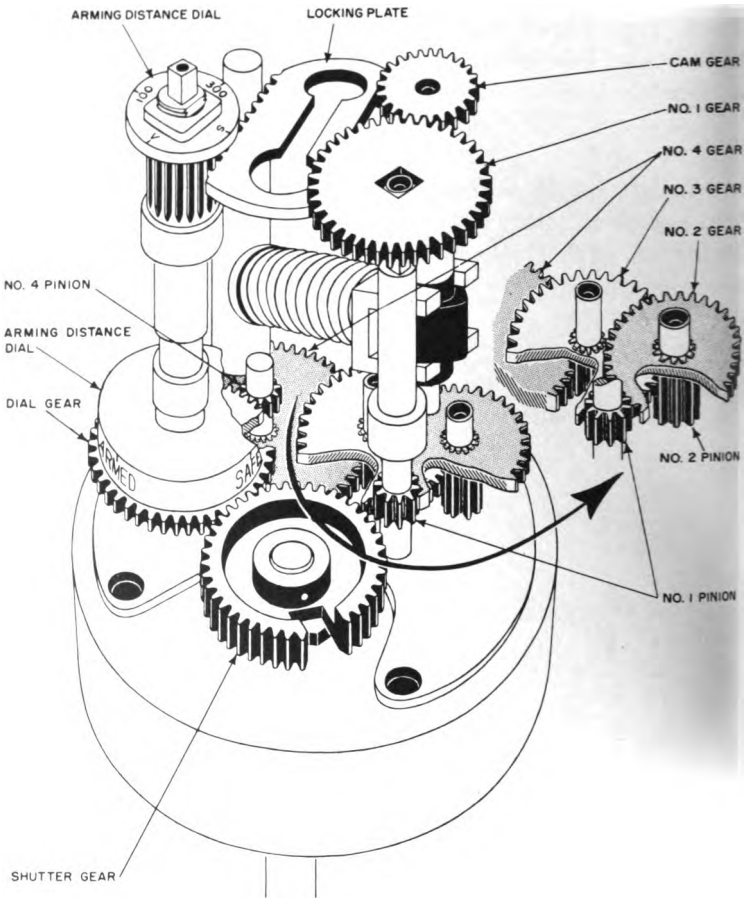

Figure 7–8.—Gear train.

spindle passes through the circular opening in the locking plate, and bears against the spring-loaded impeller plunger. The spur gear on the impeller shaft engages the No. 1 gear (fig. 7–8) of the gear train. But note that you can't leave the impeller in the exploder while the distance dial is set on SAFE. If you release the impeller,

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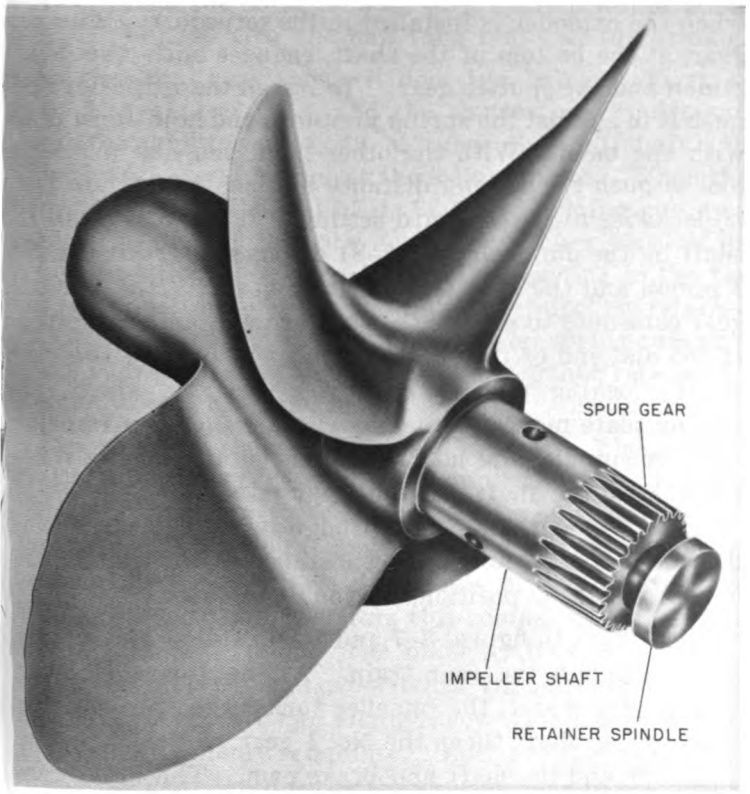

Figure 7–9.—Impeller and impeller shaft.

the spring pressure on the impeller plunger will push the impeller out of the exploder. You must install the impeller, and simultaneously set the arming distance dial at 300 yards, immediately before loading the torpedo in the tube.

Now locate the arming distance dial and its shaft in figure 7–8. The pinion at the top of the shaft engages a rack on the locking plate. (Note that in this discussion the terms "top" and "bottom" refer only to the pictures; the dial end of the shaft will be forward, not at the top,

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when the exploder is installed in the torpedo.) The dial gear, at the bottom of the shaft, engages both the No. 4 pinion and the shutter gear. To install the impeller, you push it in against the spring pressure, and hold it in place with one hand. With the other hand you use a special tool to push the arming distance dial shaft in, then turn it clockwise to the 300-yard setting. When you push the shaft in, the dial gear (fig. 7–8) disengages from the No. 4 pinion and the gear train that drives it. But the dial gear continues to engage the shutter gear, and the pinion at the dial end of the shaft continues to engage the rack on the locking plate. When you turn the shaft, the locking plate moves so that its slot engages the impeller retainer spindle, and holds the impeller in place. When you release the shaft, the dial gear re-engages the No. 4 pinion. The shutter gear, through its shaft, has moved the detonator shutter a short distance. But the shutter is still in a safe position, as you'll see later.

Check back to figures 7–7 and 7–8 to follow the arming action through the gear train. As the torpedo travels through the water, the impeller turns; the spur gear on the impeller shaft turns the No. 1 gear, which turns the cam gear and its shaft and brake cam. The brake cam is a safety feature. As you can see in figure 7–7, it bears against a spring-loaded yoke. The yoke resists the turning motion of the cam, and thus tends to keep the impeller and gear train from turning. Not until the torpedo reaches a speed of about 8 knots is there enough force on the impeller to overcome the resistance of the brake cam.

The No. 1 gear, through its shaft, also turns the No. 1 pinion. Follow the turning force through the diagram, figure 7–8: No. 1 pinion to No. 2 gear; No. 2 pinion to No. 3 gear; No. 3 pinion to No. 4 gear; and No. 4 pinion to the dial gear. Note that in each step a small gear turns a larger one; thus the speed of rotation is greatly

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reduced, and the impeller must turn many times in order to give the dial gear the half-turn required for arming.

As the dial gear turns, it does two things. First, it turns the shutter gear, and the shutter gear shaft and detonator shutter. Second, it turns the dial shaft and pinion, and therefore moves the locking plate. When the torpedo reaches the end of its 300-yard arming run, two things happen. First, the detonator shutter reaches its armed position. Second, the circular opening in the far end of the locking plate reaches the impeller retainer spindle. This releases the impeller; and spring pressure ejects it from the exploder, so that no further rotation of the gear train can take place.

Figure 7–10 shows the impact section. The shutter gear at the top is turned by the arming distance dial gear. Through its shaft, the shutter gear turns the detonator shutter. The electrical connector for the cable from the torpedo power supply is upper left of center in figure 7–10. The positive lead from this connector is grounded to the exploder frame. The other (minus 24 volts) is connected to the distance switches (upper center in the figure). These are two single-throw switches connected in parallel to ensure reliability. Both are normally open. When the gear train turns the shutter gear to the armed position, both of the distance switches are closed by a cam on the detonator shutter shaft. A wire from the distance switches is connected to one side of the firing switch.

Figure 7–11 shows the Mk 3 Mod 5 inertia switch. The ball-shaped weight forms one of the two electrical contacts. The weight is held in a neutral position by spring pressure on the insulated wafer that supports its shaft. A dome-shaped metal shell around the ball forms the other contact of the switch. When the torpedo strikes the target, inertia will throw the weight forward (that's UP in fig. 7–11). Or, if the torpedo strikes a glancing blow, inertia will throw the weight sideways.

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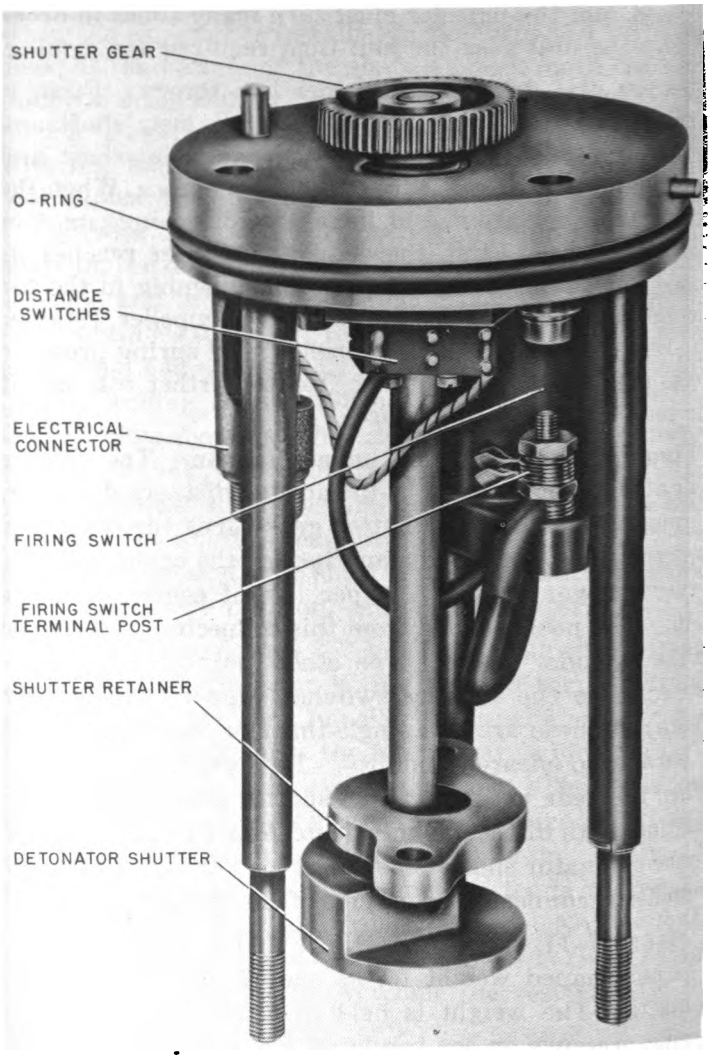

Figure 7–10.—Impact section.

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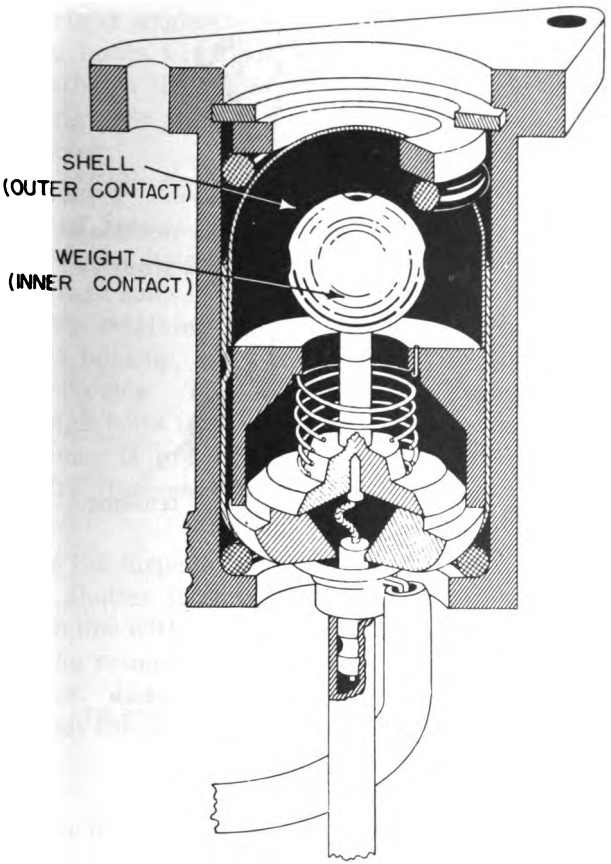

Figure 7–11.—Firing Switch (Inertia) Mk 3 Mod 5.

In either case it will touch the metal shell, and thus close the circuit to the electric primers.

Figure 7–12 is a diagram of the explosives section and the shutter shaft assembly of the Mk 11 Mod 2 exploder. The detonator shutter fits in the circular cavity in the shutter housing (shown directly under the shutter in fig. 7-12). It's held in place in the cavity by the shutter

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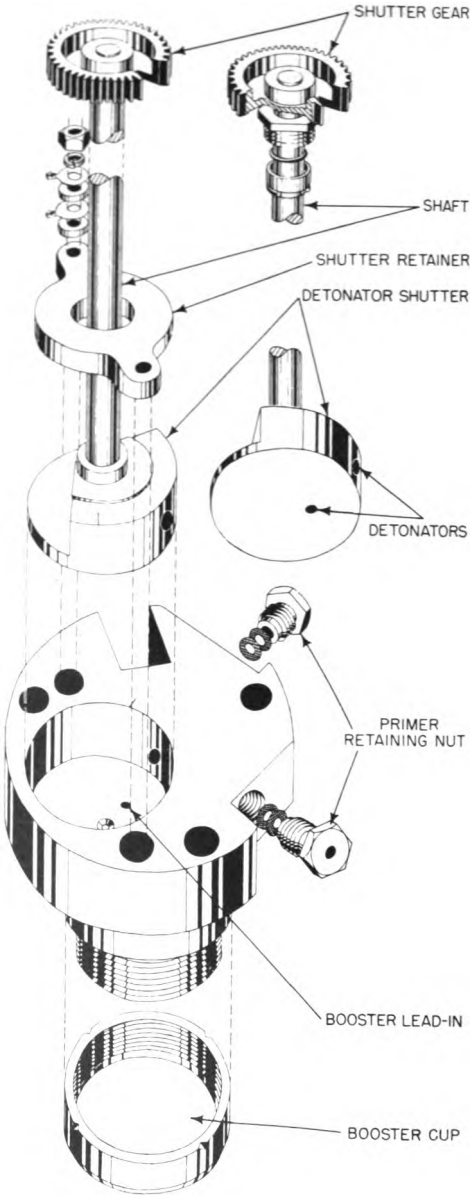

Figure 7–12.—Explosives section and shutter shaft assembly.

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retainer. Two holes are drilled in the detonator shutter —one at right angles to the shaft, and one parallel to it. These two holes join inside the shutter, and form an L-shaped path for the explosive train. A Mk 40 detonator, (containing .288 gram of lead azide) is fitted into each of the two holes.

The booster lead-in is a thin tube containing a small quantity of tetryl. It fits in an off-center hole in the bottom of the detonator shutter cavity. Two electric primers fit in holes in the shutter housing, where they are secured by retaining nuts. The two primer holes join inside the housing, and enter the shutter cavity through a hole in its side. The two wires from each primer come out through holes in the retaining nuts. One wire from each primer is grounded to the exploder frame. The other wire from each primer is connected to the firing switch.

Before the torpedo is fired, and all during the arming run, the shutter is in a safe position. The detonators are not in line with either the primers or the booster lead-in. If the primers should fire they can not explode the detonators. If the detonators should explode they would not explode the booster lead-in.

Arming and Firing Sequence

Now we'll quickly run through the series of steps in the arming and firing sequence. An instant before firing, the exploder is safe both mechanically and electrically. The detonators are not in line with the primers or the booster lead-in. The electric firing circuit is open at two points—at the two distance switches, and at the firing switch. The impeller is in place, and secured by the locking plate. The arming distance dial is set for 300 yards.

After firing, when the torpedo reaches a speed of 8 knots, the force on the impeller is strong enough to overcome the resistance of the brake cam. The impeller

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and gear train begin to turn. After a run of 300 yards, the detonator shutter has been turned far enough to line up the detonators with the primers and booster lead-in. The two distance switches have closed, so that the electric circuit through the primers is now interrupted only by the firing switch. The locking plate has released the impeller; the impeller has been ejected from the exploder, so that the gear train will turn no farther.

When the torpedo strikes its target, the weight in the firing switch is thrown forward or to the side. It makes contact with the shell of the switch, and thus closes the circuit through the two electric primers. (The two primers are connected in parallel, for extra reliability; either primer alone can fire the detonators.) The primers fire, and explode the first detonator—the one that's at right angles to the shutter shaft. The first detonator explodes the second—the one that's parallel to the shutter shaft. The second detonator explodes the booster lead-in, which explodes the booster. And the booster initiates the main charge in the torpedo war head.

Repairs and Overhaul

Exploder Mk 11 Mod 2 may be overhauled only at the following activities: U. S. Naval Underwater Ordnance Station, Newport; U. S. Naval Mine Depot, Yorktown; and U. S. Naval Torpedo Station, Keyport. Torpedo personnel aboard tenders are authorized to perform several tests on the exploder, including a torque test, distance switch test, firing switch continuity test, shutter alignment test, and pressure test. You'll find the necessary instructions and checkoff sheets in the latest revision of OP 1999.

Personnel aboard firing ships are permitted to perform only three operations on the Exploder Mk 11 Mod 2. These are installing it in the torpedo, setting its distance dial, and disarming it. Here are the steps for these three operations:

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Installation of Exploder Mk 11 Mod 2

1. Inspect the exploder well, and the threads and O-ring sealing surfaces. Make sure they are clean, and free from burrs and scratches.

2. In the bottom of the exploder well, put as many fiber spacers as you need to hold the booster firmly against the base of the exploder. (Two spacers are provided with the torpedo war head.)

3. Install a Booster Mk 9 Mod 0 in the bottom of the exploder well.

4. Pull the electric cable out of the well, far enough to connect it to the exploder.

5. Remove the exploder and impeller from the shipping container. Inspect the O-ring; if it's damaged, replace it with a new one. Coat the O-ring with silicone grease.

6. Carefully remove the shorting wire from the exploder.

7. Connect the exploder cable to the exploder.

8. Slide the exploder assembly into the well. As you do so, align the guide pin on the exploder flange with the slot in the well.

9. Remove the cover nut from the cylindrical spacer in the shipping container. Screw the nut into the well to hold the exploder in position. Tighten it securely, using the special spanner provided for that purpose.

Exploder Setting

Install the impeller and set the distance dial just before you load the torpedo in the tube. Follow these steps:

1. Place the end of the impeller shaft over the impeller plunger. Push the impeller into the exploder until it is firmly seated. You may have to turn it slightly to mesh the spur gear on the impeller shaft with the No. 1 gear.

WARNING. If you release the impeller at this point, it will spring out of the exploder with considerable force. You have to hold it in place with one hand until after you have set the distance dial.

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2. While holding the impeller in place, fit the setting wrench over the square-ended spindle of the arming distance dial. Push the wrench inward. (You can't set the dial unless its shaft is pushed in.)

3. Still holding the impeller, turn the spindle CLOCKWISE until the dial reads 300. (The dial can not be set for less than 300 yards.) Do NOT try to turn the dial counterclockwise (i.e. from SAFE to ARM to 100).

4. Remove the setting wrench, and release the impeller. The impeller should now be firmly locked in place.

Exploder Disarming

It isn't likely that you'll have to disarm the exploder after it's armed. But if a torpedo with an armed exploder should miss its target and run up on the beach, you could disarm the exploder by following these steps:

1. Disconnect the torpedo battery cables. (You'll find directions in OP 699.)

2. Push the impeller into place in the exploder, and turn it CLOCKWISE until the distance dial reads 300. While turning the impeller, you'll have to hold it in place against spring pressure until the locking slide engages the impeller locking spindle. That will take about 30 complete revolutions.

3. Fit the dial setting wrench over the shaft of the arming distance dial. Push the wrench (and shaft) inward.

4. Now, while HOLDING THE IMPELLER FIRMLY with one hand, turn the wrench COUNTERCLOCKWISE until the dial reads safe (S).

CAUTION. When you reach the "S" position, the locking slide will release the impeller. If you aren't holding the impeller firmly, it will spring out with considerable force, and may cause accidental injury.

5. Remove the setting wrench and the impeller.

6. The exploder may now be removed from the war head.

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TORPEDO EXPLODER MK 14 MOD 2

Exploder Mk 14 Mod 2 arms mechanically and electrically; on impact with the target, it fires electrically through an inertia-ball switch. It is used with the Mk 28 electric homing torpedo. Electric power for the firing circuit is provided from the torpedo power supply, through a cable connection. The inertia-ball switch is not a part of the exploder itself, but is mounted separately in the nose of the torpedo. The firing circuit is in series with a part of the torpedo homing circuit. Even when the exploder is fully armed, it can not be fired through the inertia switch unless certain conditions required by the torpedo homing program are met. You can find information on this feature in OP 691.

Exploder Mk 14 Mod 2 is shown in figure 7–13. As you can see, it is basically similar to Exploder Mk 8. It uses the same base plate, and the same gear train. But all parts associated with mechanical firing have been removed, and several parts have been added to adapt the exploder for electric firing. The base plate is a circular bronze casting, 8 inches in diameter. It fits in a flanged cavity near the after end of the war head of the Mk 28 torpedo. Its lower surface is cylindrical, to conform to the shape of the war head.

In figure 7–13 you can see the receptacle to which you connect the cable that brings power to the firing circuit, by way of the homing circuit and inertia-ball switch. The receptacle is just to the left of the gear train. At the right, below the exploder top plate, you can see a toggle switch. This is a safety feature; it is a part of the electric arming circuit.

Arming and Firing

Figure 7–14 is a cutaway view of the exploder in its unarmed position. The detonator holder is enclosed by the safety chamber, and the arming screw is engaged by the threads of the arming gear. Two leads from the

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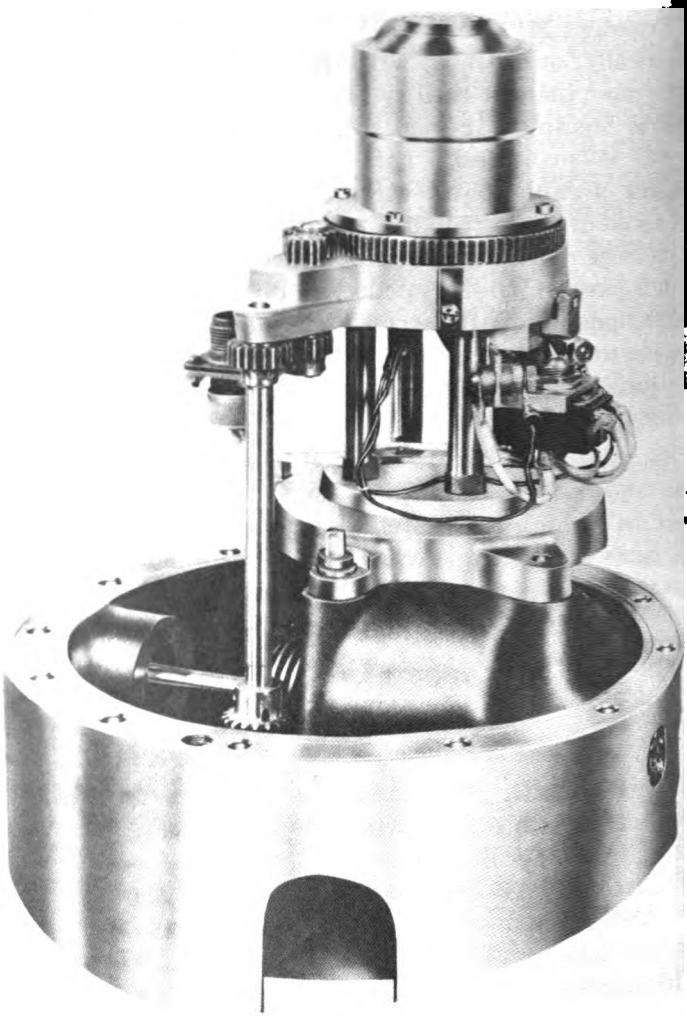

Figure 7–13.—Exploder Mechanism Mk 14 Mod 2.

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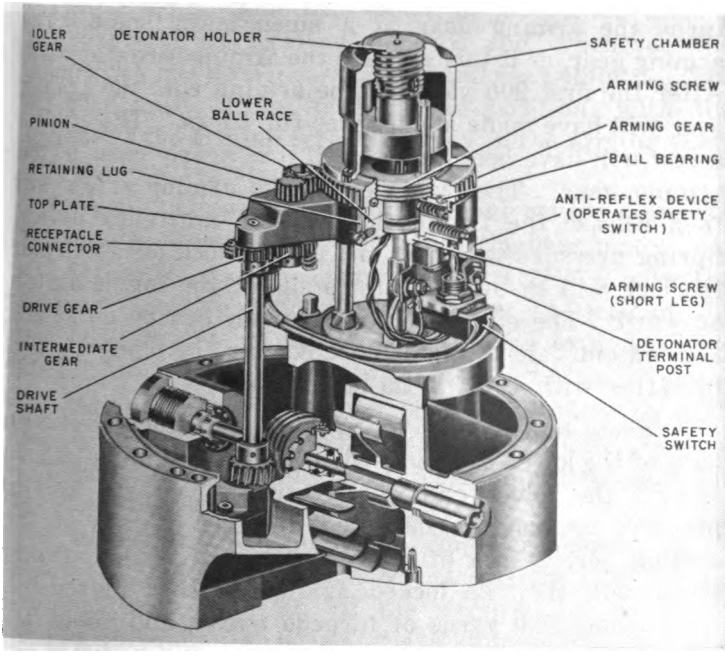

Figure 7–14.—Cutaway view of Exploder Mechanism Mk 14 Mod 2 (unarmed position).

power receptacle are connected to the outboard terminals of the double-pole double-throw toggle switch in the antireflex device. The center or transfer terminals of this switch, are connected to the two detonator leads. The two inboard switch terminals are shorted together.

The bat handle of the toggle switch is in its inboard position. The detonator leads are therefore connected to the two inner terminals, and thus shorted out. The bat handle of the switch is engaged by a hole in a spring-loaded trigger lock. The spring tends to push the trigger lock outward, but it's secured in the inboard position by the short leg of the arming screw.

When the torpedo begins its run, the impeller begins to turn. Through the vertical drive shaft and gear train, it

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turns the arming gear at a much lower speed. The arming gear, as it turns, raises the arming screw upward. After the first 200 yards of the arming run, the arming gear will have made about three full turns. The arming screw will have been lifted until it is nearly clear of the arming gear. The short leg of the arming screw will then release the trigger lock of the antireflex device. Spring pressure will snap the trigger lock outward, and the lock will throw the bat handle of the toggle switch outward. The electric detonator will then be no longer shorted out. It will be connected into the firing circuit, in series with the inertia-ball switch.

At about 3½ turns of the arming gear, the 4 steel stop balls of the lower ball race will engage the annular groove around the lower end of the arming screw. Spring pressure against the balls will lift the threads of the arming screw free of the arming gear. The arming screw will then be locked against further movement. After about 500 yards of torpedo travel, and about 7¼ turns of the arming gear, the detonator will be lifted out of the safety chamber and into the booster. The exploder will then be fully armed. When the inertia switch closes on impact, it will complete the circuit through the electric detonator. The detonator will initiate the booster, which will in turn initiate the main charge in the war head.

Maintenance and Repair

When an exploder requires extensive repairs or a complete overhaul, it should be turned in to a tender for forwarding to one of the three authorized overhaul activities mentioned earlier in this chapter. Personnel aboard submarine tenders are authorized to perform a number of tests on the Mk 14 exploder, and are provided with a limited number of spare parts. The authorized tests are described in OP 1830, First Revision, part 8. Personnel aboard submarines are authorized to perform the operations outlined below.

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TORQUE TEST. This test should be performed when a new exploder is received aboard, and whenever the stuffing box has been disassembled and reassembled. The exploder must be in its unarmed position, with the threads of the arming screw engaged in the arming gear.

1. Remove the impeller guard.

2. Turn the impeller by hand, through several complete revolutions, toward the after end of the base plate.

3. Assemble the impeller test tool (MF–7) with the adapter (tool No. 769910), and insert the legs of the adapter into the mounting holes of the exploder base plate.

4. Align the tip of the impeller test tool blade with the tip of one of the impeller blades. Rotate the tool counterclockwise, noting the force required to start the impeller blade in motion.

5. Repeat this test on several impeller blades. In all cases, the total torque must be not less than 16 ounces, and not more than 20. If the required torque is not within these limits, adjust the stuffing gland nut and repeat the test.

6. Replace the impeller guard.

EXPLODER DISARMING. Follow these steps:

1. Disengage the idler gear.

2. While pushing inward on the trigger lock of the antireflex device, press down the arming screw and turn the arming gear counterclockwise until its threads engage the arming screw.

3. While turning the arming screw counterclockwise, continue to press inward on the trigger lock until the short leg of the arming screw secures it in its inboard position.

4. Turn the arming gear counterclockwise until it reaches its limit of travel. Then turn it clockwise until the scribe marks on the arming gear and arming screw are flush and in line.

5. Re-engage the idler gear.

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TOGGLE SWITCH ELECTRICAL CHECK. Follow these steps:

1. Make sure that the mechanism is unarmed, with the trigger lock inboard.

2. With an ohmmeter, check to see that there is NO continuity between the following points (tool No. WU-64482):

a. Each detonator terminal and the detonator terminal holding bracket or exploder base.

b. Between each detonator terminal and each pin of the connector plug.

c. Between all terminals and the exploder base.

3. Check for continuity between the detonator terminals.

4. Connect a jumper across the detonator terminals.

5. Disengage the idler gear, and arm the exploder by turning the arming gear clockwise until the antireflex device snaps out and throws the toggle switch.

6. There should NOW be continuity between the pins of the connector plug assembly. Check it with an ohmmeter. If there is no continuity, the toggle switch is defective, and the exploder should be returned to the tender.

7. Disarm the exploder.

AIR LEAKAGE TEST. This is the last test to be performed before installing the mechanism in the torpedo war head. The test requires the use of a dummy war head.

1. Blow out the exploder base with low-pressure air.

2. Turn the exploder on its side, and install lifting screws on the outside of the base (tool MF-2).

3. Remove the impeller guard.

4. Inspect the base plate for any dents that might affect its installation. Look for dents or scratches that might prevent a good seal against the gaskets.

5. Install a gasket and guide pins on the exploder cavity flange of a dummy war head (tool No. 487).

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6. Install the exploder in the dummy war head, fitting it carefully over the guide screws.

7. Remove the guide screws. Insert the holding screws, and tighten them uniformly (tool No. 49).

8. Remove the test plug from the base plate, and install test fixture (751414) in the test plug hole.

9. Apply 10 pounds of air pressure to the exploder cavity; then remove the air line. Watch the gage of tool No. 751414; the gage should show no pressure drop during five minutes. If there is no pressure drop, remove the test fixture and skip to step 16.

10. If the gage shows a pressure drop in five minutes or less, use a cofferdam assembly (SG–6278) over the dummy war head. Pour water into the cofferdam until it covers the base plate.

11. Check for air bubbles at the impeller shaft. Turn the impeller a few turns by hand, but be careful not to make any bubbles that you might mistake for leakage.

12. Check for bubbles around the holding screw holes. (Leakage here might be due to either a defective gasket or an improperly seated gasket.)

13. Check for leakage at the flange of the arming mechanism cable (through the depth disarming switch hand hole).

14. When you find the point of leakage, correct the cause and repeat the test.

15. After a satisfactory leakage check, drain the water from the cofferdam and remove the test fixture.

16. Replace the test plug, using a new washer (tool MF–18).

17. Replace the impeller guard and secure it with six screws.

18. Remove the exploder from the dummy war head (tool No. 49, MF–2).

SAFETY

The training courses for TM 3&2 give a complete list of safety precautions; we won't repeat them here. But the following points deserve emphasis:

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Exploders must not be installed in war heads except when torpedoes are loaded in tubes (or, when so ordered, when torpedoes are on ready racks of submarines).

Detonators and boosters must be handled with extreme care.

When you disarm an Exploder Mk 11 Mod 2, it will eject its impeller with considerable force when the dial reaches the SAFE position. To avoid injury, hold the impeller securely with one hand while you turn the dial shaft with the other.

In the shutter-alignment test of the Mk 11 Mod 2 (performed aboard tenders), you have to determine when the detonators are in line with the primers. Do this by sighting through the primer holes. DO NOT try to feel the position of the detonator by reaching through the primer hole with a scriber or any other tool. A slight pressure from such a tool might fire the detonator.

Torpedo exploders should be handled only by experienced personnel. This applies to packing and unpacking, assembling, installing, disarming, testing, and all phases of maintenance and repair. As a TM 1 or C, you will be responsible for enforcing this regulation. When you're training inexperienced personnel in any operation involving an exploder, give them the closest possible supervision at all times, and at every step.

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QUIZ

1. This chapter describes three exploders: Mk 6 Mod 13, Mk 11 Mod 2, and Mk 14 Mod 2. Each of the following statements applies to one or more of these three marks of exploder. Indicate which. (For example: a.—Mk 6.)
   a. Used with Torpedoes Mk 14, 15, 16, and 23.
   b. Used with Torpedo Mk 27.
   c. Used with Torpedo Mk 28.
   d. Mounted in nose of torpedo.
   e. Mounted on rectangular base plate, in ogival part of war head.
   f. Mounted on circular base plate, in cylindrical part of war head.
   g. Arming screw always in armed position.
   h. Impeller has 15 blades.
   i. Impeller has 4 blades.
   j. Distance dial can be set at 300 yards or SAFE.
   k. Safety delay switch operated by worm gear on vertical drive shaft.
   l. Antireflex device operated by trigger lock.
   m. Distance switches operated by cam on shutter shaft.
   n. Two detonators at right angles to each other.
   o. Detonator terminals shorted by toggle switch when exploder is unarmed.
   p. Ejects its impeller on arming.
   q. Power for firing circuit stored in a capacitor.
   r. Arms both mechanically and electrically.
   s. Firing circuit may sometimes be disabled by a part of the homing circuit.
   t. Fires electrically through inertia-ball switch.
   u. Explosive train includes a booster lead-in.
   v. Idler gear may be disengaged from arming gear.
   w. Power for firing circuit provided by a generator.
   x. Power for firing circuit provided by torpedo power supply.
   y. Basically similar to Exploder Mk 6 Mod 10.
   z. Basically similar to Exploder Mk 8.

2. As in question 1, indicate which mark of exploder each of these statements applies to:
   a. Pickup coil provides proper balance and trim.
   b. Impeller turns on athwartship shaft.
   c. Water flows through impeller channel in base plate.
   d. Impeller turns on fore-and-aft axis.
   e. Arming action lifts detonator out of safety chamber.
   f. Arming action aligns detonators with primers.

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g. Firing circuit voltage controlled by a regulator tube.
h. Arming distance 300 yards.
i. Arming distance 400 to 450 yards.
j. Must be returned to authorized shore station if overhaul is required.
k. Cofferdam required for pressure test.
l. Impeller seats on spring-loaded plunger.
m. Shorting bar must be removed before installing exploder in war head.
n. Gear train operated by spur gear on impeller shaft.
o. Gear train operated by worm gear on impeller shaft.
p. Gear train operated by worm gear on generator shaft.
q. Dial shaft pinion moves the impeller locking plate.
r. Two electric primers connected in parallel.
s. Impeller rotation resisted by brake cam.
t. Fiber spacers hold booster against exploder base.
u. Capacitor charging current limited by a resistor.
v. Arming distance about 500 yards.
w. Guide screws used during installation in exploder cavity of war head.
x. Exploder cavity sealed by a gasket.
y. Exploder cavity sealed by an O-ring.
z. Should be handled only by experienced personnel.

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CHAPTER 8

ELECTRIC TORPEDOES

This chapter is a short review of Torpedo Mk 18 Mod 2. For security reasons, this is the only electric torpedo we can discuss in detail in an unclassified book. Almost all of the homing torpedoes are powered by electricity. In the Mk 18 Mod 2, energy comes from a lead-acid storage battery. Most of the homing torpedoes use batteries of a different type. In the Mk 18 Mod 2, you set the gyro and depth mechanisms mechanically. In the homing torpedoes, and in a later mod of the Mk 18, these settings are electric. We'll discuss homing torpedoes, the new batteries, and electric gyro and depth setting in volume 2 of this course.

Although the Mk 18 torpedo has been in the fleet since 1943, many Torpedoman's Mates have never had a chance to work with it. If you are one of them, use this chapter as an introduction; then study the details in OP 946. If you've actually worked with the Mk 18, use this chapter for a quick review.

IN GENERAL

The Torpedo Mk 18 Mod 2 is 20½ feet long. Its diameter is the same as that of Mks 14 and 15—21 inches. It weighs one and a half tons. The Mk 18 is fired only from the submerged tubes of submarines. A torpedo gets a severe shock when it strikes the water after you fire it from a deck tube. The Mk 18 isn't built to take that shock.

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The Mk 18 torpedo makes an average speed of 29 knots, for an effective range of about 4,000 yards. As you can see, the speed is slow and the range is short, compared with those of an air-steam torpedo. But, for submarine use, the Mk 18 torpedo has an advantage that often outweighs its low speed and limited range. The electric torpedo leaves practically no wake. There are two reasons why that's important. If the enemy can't see the torpedoes coming, he can't maneuver to avoid them. And this is even more important; a wakeless torpedo doesn't give away the sub's position. When a submarine attacks a bigger ship, its fighting effectiveness depends on staying hidden. The long wake of an air-steam torpedo points out the sub's general position very clearly.

In many of its parts, the Mk 18 is much like an air-steam torpedo. Its war head, exercise head, control mechanisms, and steering mechanism are similar to those of a Mk 15 torpedo. The big difference is in the propulsion mechanism. An air-steam torpedo stores mechanical energy in its compressed air, and chemical energy in its fuel. To make this stored energy turn the propellers, it uses a superheating system, a pair of turbines, and a gear-reduction engine. The Mk 18 Mod 2 stores chemical energy in its battery. It uses an electric motor to apply this stored energy to the propellers. The Mk 18 has no reduction gears; the propellers turn at the same speed as the motor armature —1660 rpm.

The torpedo Mk 18 Mod 2 is made up of four main sections; each of them can be detached as a unit from the adjoining sections.

THE HEAD SECTION. The WAR HEAD contains the main charge of high explosive, and the exploder mechanism for detonating it. The EXERCISE HEAD carries expendable liquid ballast, and an air-release mechanism and discharge valve to expel the ballast at the end of the exercise run.

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THE BATTERY COMPARTMENT corresponds to the air flask section of an air-steam torpedo. It houses the batteries that supply energy to the motor. This section takes up about half of the torpedo's total length; with the batteries installed, it accounts for about half the total weight.

The AFTERBODY houses the electric motor and drive shaft, the control mechanisms, and the compressed air supply that spins the gyro and operates the steering engines. The afterbody joins the battery compartment directly; the Mk 18 torpedo has no midship section.

The TAIL carries the tail fins, rudders, and propellers.

HEAD SECTION

War Head

Figure 8–1 shows the war head of a Mk 18 torpedo, partly cut away. As you can see, the nose is ogival; the rest of it is cylindrical. The war head shell is made of steel. (In the Mks 14 and 15, you remember, it's made of phosphor bronze.) The joint ring at the after end of the shell is drilled and tapped for the joint screws that secure the war head to the battery compartment. An inner flange on the joint ring supports a concave steel

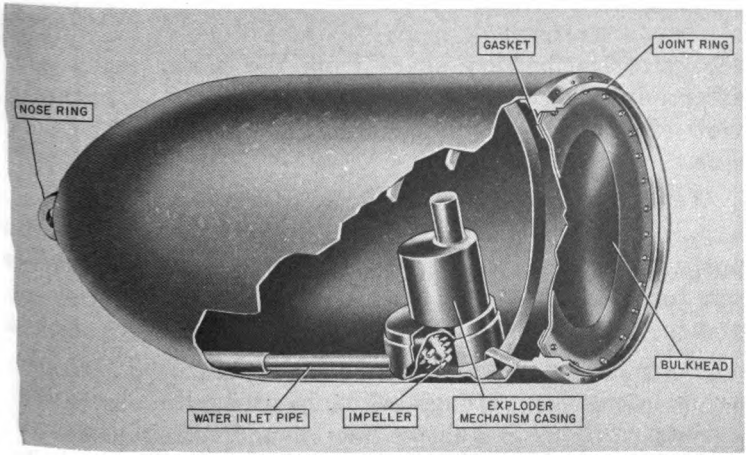

Figure 8–1.—War Head, partially cut away.

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bulkhead. When the bulkhead is bolted in place with its gasket, it forms a watertight closure for the after end of the warhead. There are three tapped holes in the bulkhead rim. By inserting a special tool in these holes, you can break the bulkhead joint when necessary.

The war head now used with Torpedo Mk 18 Mod 2 is designated War Head Mk 18–4. Its main charge consists of 595 pounds of HBX. An earlier war head, the Mk 18–2, was charged with a mixture of high explosives, mainly torpex.

Exploder

Note, in figure 8–1, that the exploder mechanism casing is near the after end of the war head. The water that drives the impeller is brought in through a water inlet pipe. The exploder currently in use with Mk 18 torpedoes is Exploder Mechanism Mk 8 Mod 7. It's provided with an inertia ring, and fires mechanically on impact. You'll find a description of it in OP 1830.

BATTERY COMPARTMENT

The battery compartment is a cylindrical shell approximately 126 inches long. The compartment is open at its forward end; near the after end, a bulkhead separates the battery space from the motor space and afterbody. Figure 8–2 (in two parts) is a cutaway view of the battery compartment, looking from the port side.

Welded to plates on the bottom of the compartment is a pair of tracks, on which you slide the battery into position. The forward and after battery braces prevent any fore-and-aft motion of the battery after it's in place, and the holding-down rod assemblies hold it on the tracks.

Along the top of the battery compartment is a series of seven handholds, through which you have access to the battery. Figure 8–3 shows how a handhold cover fits on its flange. The spider has three legs, the tips of which are secured in a groove in the flange. (One of these slots

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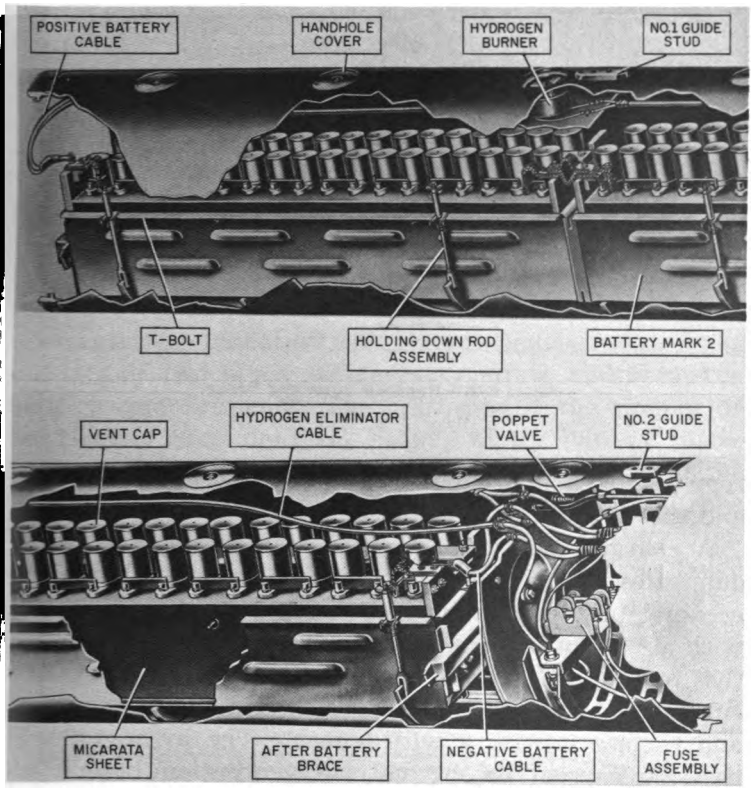

Figure 8–2.—Battery compartment, cutaway view from port side.

is visible in figure 8–3.) The cover is secured to the spider by a single bolt. A gasket on the flange, and another under the head of the bolt, make watertight seals when the handhole cover is bolted in place.

Of the seven handholes in the battery compartment, only one is aft of the bulkhead. Figure 8–2 shows a "hydrogen burner" mounted on the spider of the No. 3 handhole, and a "hydrogen eliminator cable" leading aft from the burner. The hydrogen burner has now been

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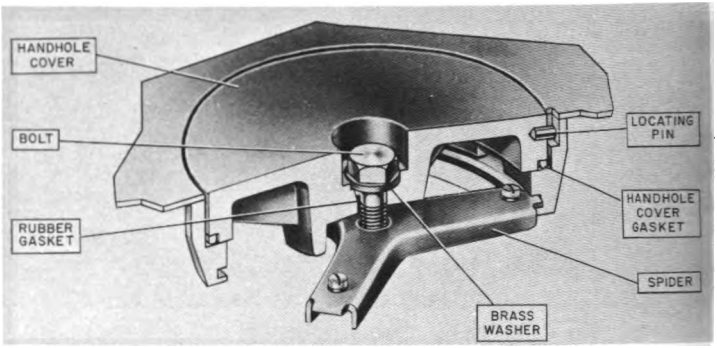

Figure 8–3.—Handhole cover and flange.

replaced by a hydrogen eliminator of a different type, and the cable is no longer used.

A charged storage battery constantly gives off small quantities of hydrogen. If this hydrogen is allowed to accumulate inside the battery compartment, it will mix with air to form a dangerous explosive mixture. When the torpedo is stowed in the torpedo rack of the submarine, you can remove one of the handhole covers and replace it with a wire screen. The hydrogen will then be carried off by natural ventilation before an explosive mixture can form. But when the torpedo is in a submarine tube, the hydrogen must be removed by some other means.

The principal part of the hydrogen burner was a wire filament, which was kept at red heat by an electric current. The heat of the hydrogen burner caused the hydrogen to combine with the oxygen of the air to form water vapor, thus preventing the accumulation of enough hydrogen to form an explosive mixture.

The newer type of hydrogen burner contains a small quantity of palladium—a chemical catalyst. In the presence of palladium, hydrogen will combine harmlessly with oxygen to form water vapor. No heat or electric current are necessary. The new hydrogen eliminator,

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like the old one, is mounted on the spider of the number 3 handhole.

Ventilating System

The hydrogen eliminator can work only when the battery compartment has a supply of oxygen. For that reason the air in the battery compartment must be changed from time to time, to replenish the oxygen. The ventilating system makes it possible to supply air to the battery compartment without removing the torpedo from the tube.

Figure 8–4 is a diagram of the ventilating system. It consists of two pipes, which carry air to and from the battery compartment. The inlet pipe is the smaller of the two. It runs along the bottom of the battery space, in the center of the battery track, and releases air at the forward end of the compartment. The outlet pipe runs aft from a nipple in the upper part of the battery compartment bulkhead. Both pipes open through a flange in the upper, starboard side of the afterbody.

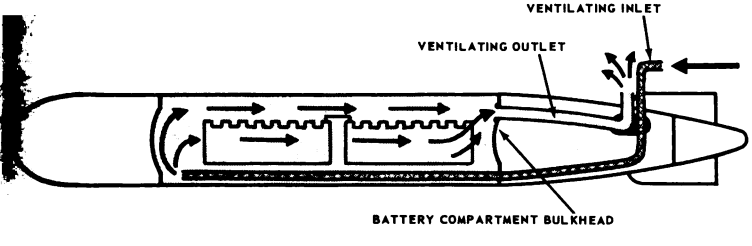

Figure 8–4.—Ventilating system.

To renew the air in the battery compartment, you connect an air hose to the inlet pipe at the ventilating fixture. Use low-pressure air—about 200 psi—and ventilate for three minutes.

Poppet Valve

At all points where air pipes or cables pass through the battery compartment bulkhead, packing is used to

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restrict the flow of gases between the battery space and the afterbody. During the torpedo run, when the battery is discharging rapidly, it forms hydrogen much faster than the hydrogen elminator can remove it. This hydrogen must be kept out of the afterbody; if an explosive mixture formed in the afterbody, a spark from the motor brushes or the starting switch would be very likely to cause an explosion.

The poppet valve is mounted in an opening near the top of the battery compartment bulkhead (fig. 8-2). While the torpedo is under way, the compressed air used by the gyro spinning mechanism, and by the depth and steering engines, exhausts into the afterbody space. The poppet valve prevents an excessive pressure buildup in the afterbody by exhausting some of this air into the battery space. At the same time, it prevents any flow of gases from the battery space to the afterbody.

Figure 8-5 is a cutaway view of the poppet valve. Its principal parts are a valve body, valve stem, and spring. The valve body screws into the after side of the battery compartment bulkhead. (The right-hand end of the

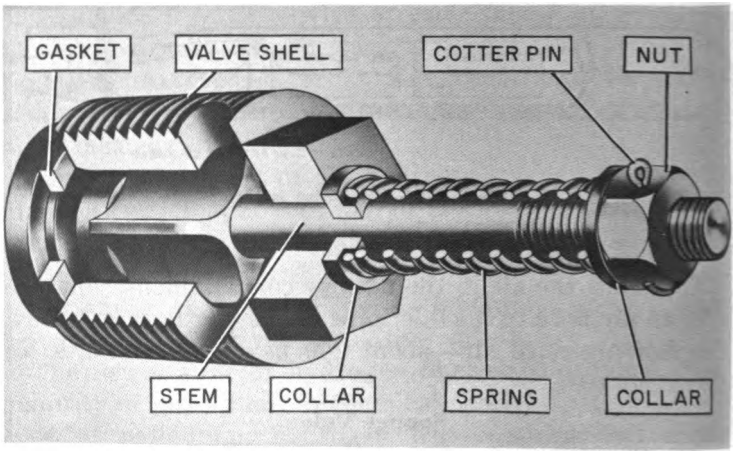

Figure 8-5.—Poppet valve.

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diagram is aft.) The spring controls the pressure at which the valve will open. You can adjust this pressure by turning the nut; the cotter pin secures your adjustment. You will adjust the valve to open at a pressure of about 3 psi.

The air in the afterbody is in direct contact with the valve, through holes in the valve shell. When the pressure in the afterbody exceeds that in the battery space by 3 psi, it forces the valve off its seat. Air exhausts into the battery space until the pressure difference falls below 3 psi.

Battery Mk 2

The Mk 2 battery consists of 72 storage cells, assembled in groups of four cells each. Nine of these 4-cell units are assembled in a sheet steel tray, and two of these trays make up the complete battery.

All of the cells are connected in series, with the positive terminal of one cell connected to the negative terminal of the next. The positive terminal of the battery is at the forward end, and the negative terminal at the after end. Because of this, there is no high voltage between adjacent cell connectors. All the cells are numbered, for reference. The number one cell is at the negative terminal of the battery, and the numbering system follows the electric circuit through the battery, to the number 72 cell at the positive terminal. Figure 8–6 shows the numbering system. By following the numbers, you can trace the circuit through the battery.

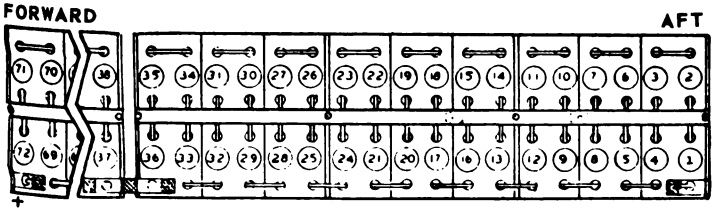

Figure 8–6.—Cell-numbering system.

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Figure 8–7 shows one of the four-cell units that make up the battery. Figure 8–8 is a cutaway view of the same unit, with the contents of three cells removed. As you can see, a number of plates are connected, in parallel, to each terminal. (Each positive plate is between two negative plates; each negative plate, except the two outside ones, is between two positive plates.) The plates are mounted close together, to keep the internal resistance of the battery low. The rubber separators between plates keep them from touching each other and short-circuiting.

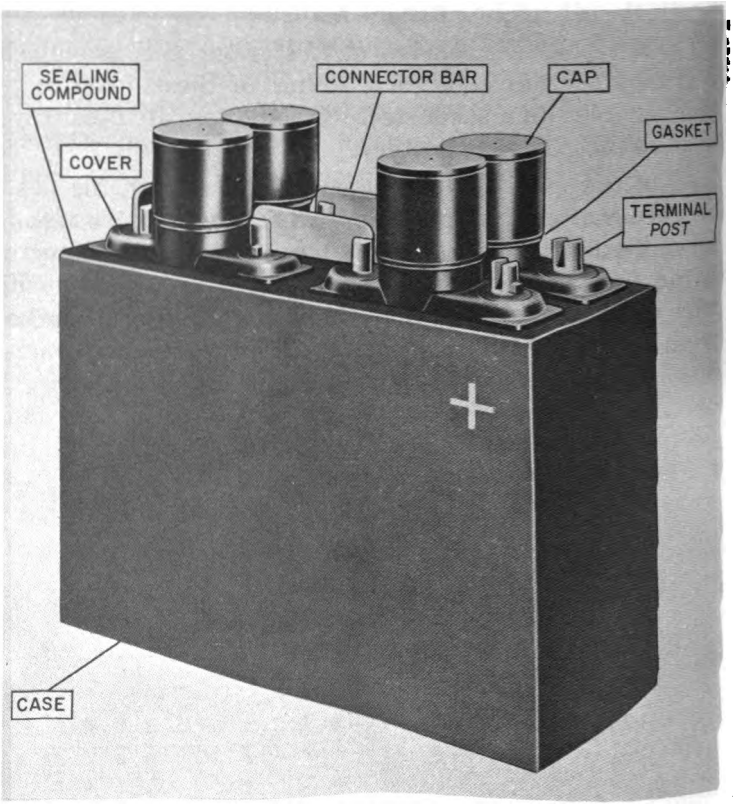

Figure 8–7.—Four-cell battery unit.

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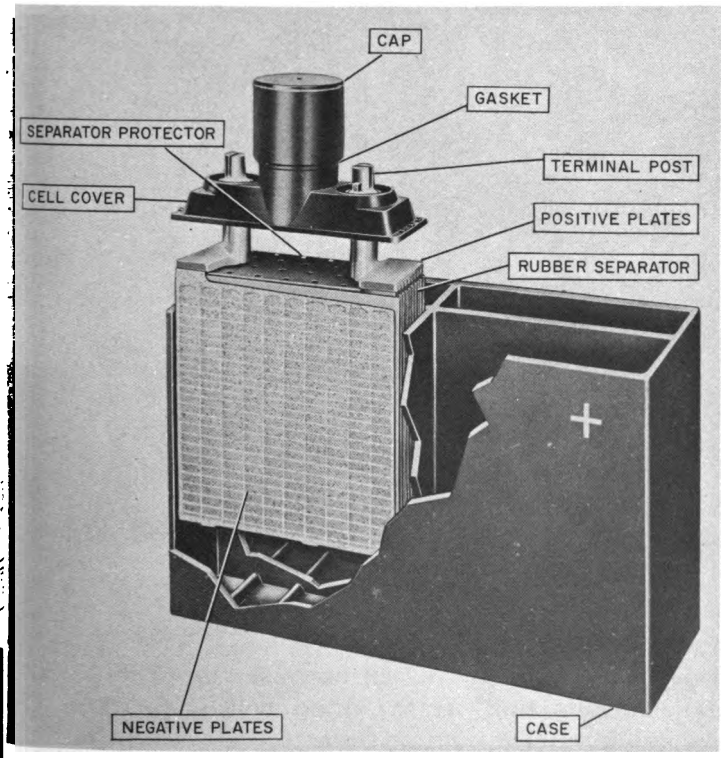

Figure 8–8.—Cutaway view of a battery cell.

Figure 8–9 is a closeup view of a cell cover. Any gas that's generated inside the cell can escape through the drain hole into the cap, and from there through the vent at the top. The cap, if you remember to screw it on tight, gives the cell a non-spill feature. If the battery is tilted, any electrolyte that may run out through the drain holes will be trapped inside the cap. When the battery is righted again, the electrolyte will flow back through the drain hole.

When you assemble the cell units in the battery trays, make sure the drain holes are forward. When a tor-

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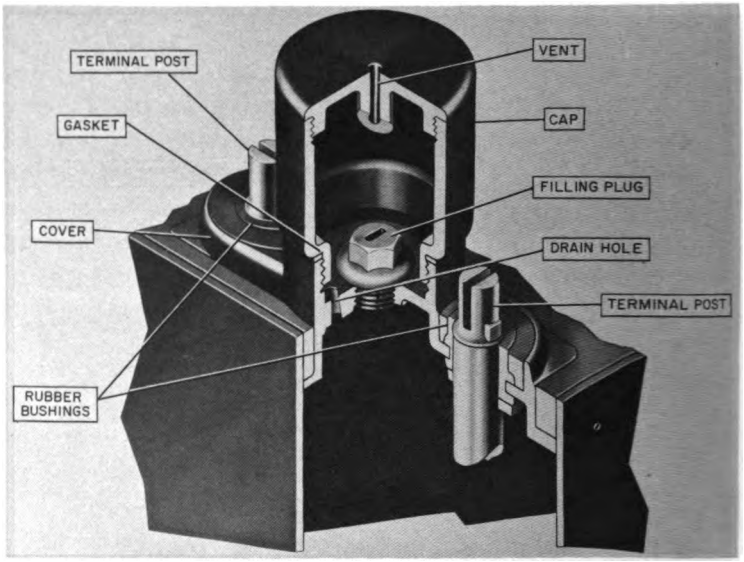

Figure 8–9.—Cutaway view of the cell cover.

pedo reaches the end of an exercise run, it practically stands on its tail. If the drain hole is forward, less electrolyte will run out into the cap.

To connect the cells in series, you must of course connect the positive terminal of one cell to the negative terminal of the next. To prevent mistakes, the terminal posts are polarized so that you can recognize them at a glance. Figure 8–10 shows you what they look like.

Chemical Action in the Battery

You probably know, in a general way, what's in the battery: positive plates of lead peroxide, negative plates of sponge lead, and an electrolyte of dilute sulfuric acid. And you know in a general way what happens when the battery discharges. A chemical reaction inside the battery changes the stored chemical energy into electrical energy.

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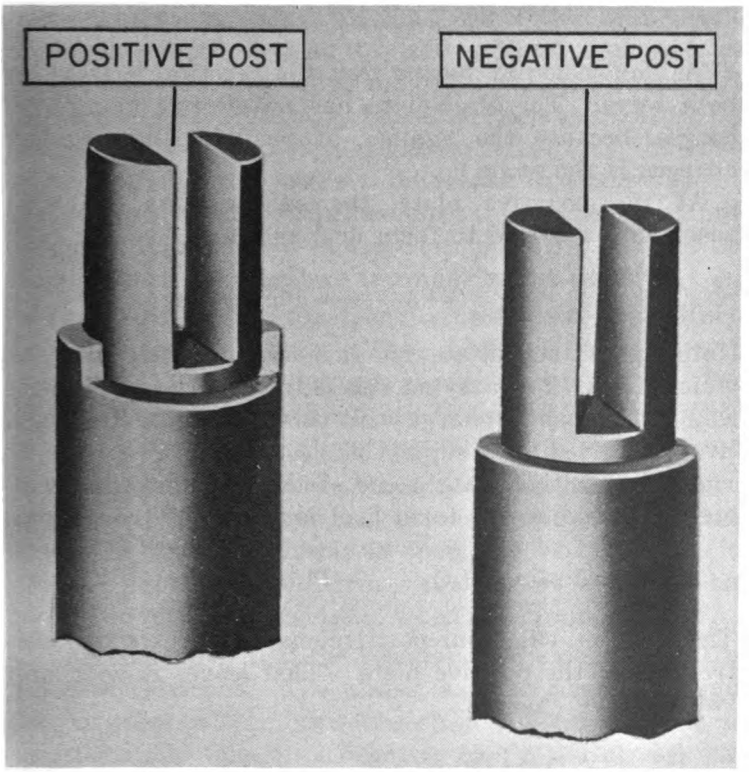

Figure 8–10.—Cell terminal posts.

Let's take a quick look at the equations for the chemical reaction that takes place in the battery. We know chemical equations aren't much fun, except for chemists. But an equation is an exact statement of what happens, and a look at the equations is the quickest way to find out exactly what goes on in the battery. (If this whole subject is new to you, read the section on Chemical Changes in Chapter 3 of *Torpedoman's Mate 3&2* Vol. 1, NavPers 10155.)

First, let's see what happens to the electrolyte. Some of the sulfuric acid molecules break up into ions, each with an electric charge.

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$$H_2SO_4 \rightleftarrows 2H^+ + SO_4^{--}$$

(The double arrow means that the reaction is working both ways. The electrolyte has no electric charge, of course, because the number of positive and negative charges is the same.)

At the negative plate, the sulfate ions (SO_4^{--}) react with the lead to form lead sulfate.

$$SO_4^{--} + Pb \longrightarrow PbSO_4 + 2e$$

Notice that the sulfate ion has two negative charges, which means it's carrying two extra electrons. But the lead sulfate has no charge. So this reaction at the negative pole gives up a supply of electrons.

At the positive plate, some of the lead peroxide combines with water, to form lead ions and hydroxyl ions.

$$PbO_2 + 2H_2O \longrightarrow Pb^{++++} + 4OH^-$$

The lead ion, with four positive charges, draws two electrons from the positive plate. That leaves it with only two positive charges.

$$Pb^{++++} + 2e \longrightarrow Pb^{++}$$

And finally, the lead ion combines with a sulfate ion to form lead sulfate.

$$Pb^{++} + SO_4^{--} \longrightarrow PbSO_4$$

At each plate, the reaction uses sulfate ions from the sulfuric acid, but not the hydrogen ions. So there will be extra hydrogen ions in the solution. And the reaction of lead peroxide and water at the positive plate produces extra hydroxyl ions. These combine with the extra hydrogen ions to form water.

$$OH^- + H^+ \longrightarrow H_2O$$

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To summarize, we can say that the reaction at the negative plate changes lead to lead sulfate, and releases electrons. The reaction at the positive plate changes lead peroxide to lead sulfate, and absorbs electrons. Since the reactions give one plate a negative charge, and the other a positive charge, there's a difference in electric potential between them. If you connect them through an outside circuit, a current of electrons will flow through the circuit from the negative terminal to the positive.

The two reactions together use up some of the sulfuric acid, and produce water. That should check pretty well with what you've learned through experience. You probably know that as a battery discharges, its electrolyte gets weaker—the acid becomes more and more diluted.

Now give a little more thought to these two chemical reactions. You can see that if these reactions take place when the external circuit is open, the battery will discharge itself without doing any useful work. What stops the chemical reactions when the circuit is open?

You remember that the reaction at the negative plates releases electrons. The plates, and the negative terminal of the battery, can absorb a certain number of electrons and take on a negative charge. But they can absorb only a limited number of electrons. When they can absorb no more, the reaction must stop.

And the reaction at the positive plates must take up electrons. The positive plates and the positive terminal will give up a certain number of electrons, and take on a positive charge. But when they have no more "loose" electrons to give, the reaction must stop.

But you can start the reactions again whenever you want to, simply by closing the external circuit. In that way you drain off electrons from the negative plates, so that the reaction can proceed. And you supply electrons to the positive plates, so that the reaction there can proceed. The force that drives the electrons through the external circuit—the difference in potential between the

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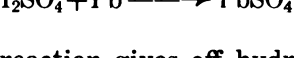
two terminals—can be made to do useful work. In the Mk 18 torpedo, we make it turn the motor armature.

Here's something else you probably know from experience: if you let a charged battery stand without recharging, it will slowly discharge itself. How does that happen? In two ways.

First, there's a small leakage of current across the outside of each cell cover—especially if it's dirty or damp. Suppose, for example, that the resistance across the cell cover is two million ohms. You'll have a leakage of one microampre across the top of the cell. That's a very small current, but in time it will discharge the battery. And there's bound to be some leakage across the inside of the cell cover, which can't help being damp.

More important, the battery also discharges itself by internal action. The sulfuric acid of the electrolyte will slowly attack the lead and turn it to lead sulfate, without having to give up electrons.



$$H_2SO_4 + Pb \longrightarrow PbSO_4 + H_2$$

Note that this reaction gives off hydrogen. The hydrogen bubbles out of the electrolyte, diffuses through the vent hole, and enters the battery compartment.

And there you have a theory that explains two of the things you already know about the torpedo storage battery.

1. A charged battery will slowly discharge itself. To keep it in top condition you have to recharge it regularly.

2. A charged battery gives off hydrogen, which collects in the battery space of the torpedo.

When a battery is COMPLETELY discharged, both plates are converted to lead sulfate. Theoretically then, it makes no difference which way you recharge the battery. Theoretically, you can make either plate positive, and the other negative. But in actual practice that won't work. Why not? Because the discharge never goes quite to

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completion. There's always some lead peroxide left on the positive plates, and there's always some sponge lead left on the negative plates. So, when you recharge a battery, the negative terminal of the charging circuit must always be connected to the negative terminal of the battery.

Here's something else to remember. If you let a partially discharged battery stand without recharging it, it will be permanently damaged. Why? Because its plate will become SULFATED.

You already know that the plates become covered with lead sulfate during a normal discharge. Then what do we mean by the term SULFATE? It refers to an abnormal form of lead sulfate. Chemically, it's the same stuff. Physically, it's in a different form. The smallest grains of sulfate will slowly dissolve in the electrolyte, and then precipitate on the larger grains. That builds up a coarse-grained layer of sulfate all over the plate. When you try to recharge a sulfated battery, the coarse-grained material resists the action of the electrolyte, and the battery won't take a full charge.

There are various ways to doctor a sulfated battery, to get a little more life out of it. But you can never bring it back to full efficiency without completely rebuilding it.

There's another way in which the plates can easily be damaged. If you let the electrolyte level fall below the tops of the plates, the exposed parts will become sulfated. From then on, you'll have only part of a battery.

Here are three easy rules to prevent sulfation before it starts:

1. Always keep the electrolyte level above the tops of the plates.

2. Never let the battery discharge completely.

3. Don't let the battery stand for any length of time with a partial charge. Recharge it regularly.

You know how to recharge a battery—by forcing a current through it in the opposite direction. To do that you

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apply a negative potential, from an outside source, to the negative terminal of the battery. And you apply a positive potential to the positive terminal. Now let's take a look at what happens inside the battery during a recharge.

A large part of the electrolyte, you remember, has been converted into water. Some of this water breaks up into ions.

$$H_2O \rightleftharpoons H^+ + OH^-$$

At both plates, some of the lead sulfate is ionized.

$$PbSO_4 \rightleftharpoons Pb^{++} + SO_4^{--}$$

At both plates, the sulfate ions combine with hydrogen ions from the water, to make sulfuric acid.

$$2H^+ + SO_4^{--} \longrightarrow H_2SO_4$$

At the negative plate, you remember, you're supplying a negative potential from an outside source. The lead ions on the negative plate take up electrons from the outside source, and become lead.

$$Pb^{++} + 2e \longrightarrow Pb$$

At the positive plate, you're supplying a positive potential. The lead ions at the positive plate give up two electrons, to become ions with four positive charges each.

$$Pb^{++} - 2e \longrightarrow Pb^{++++}$$

These new lead ions combine with hydroxyl ions from the water, to form lead peroxide and water.

$$Pb^{++++} + 4OH^- \longrightarrow PbO_2 + 2H_2O$$

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To summarize the reaction during charging; at the negative plates, lead sulfate is changed to lead; at the positive plates, lead sulfate is changed to lead peroxide; in the electrolyte, some of the water is changed to sulfuric acid.

You already know that you can't recharge a battery just by adding acid. Now you can see why. To test the battery condition, you measure the concentration of acid by measuring the specific gravity of the electrolyte. But it isn't the condition of the acid that determines the charge on the battery. The amount of acid present merely shows you the condition of the plates. Adding more acid to a discharged battery will do nothing to change the plates back to lead and lead peroxide. You can't recharge a battery by adding acid, any more than you can heat a building by holding a match under the thermometer.

Here's something else you may know from experience. When you recharge a battery, the electrolyte gives off bubbles of gas. As you near the end of the charge the rate of gassing increases, so that you have to cut down the charging current. Now let's see why a recharge causes gassing. Some of the acid, as you know, is in the form of ions.

$$H_2SO_4 \rightleftarrows 2H^+ + SO_4^{--}$$

The hydrogen ions, because they have a positive charge, will be attracted by the negative plates. There they will pick up electrons to become hydrogen, and bubble off in the form of gas.

$$2H^+ + 2e \longrightarrow H_2\uparrow$$

The sulfate ions, having a negative charge, will move to the positive plates. There they will give up electrons, and combine with water to form sulfuric acid and oxygen. And the oxygen bubbles off in the form of gas.

$$2SO_4^{--} + 2H_2O \longrightarrow 4e + 2H_2SO_4 + O_2\uparrow$$

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Note that the two gases given off are hydrogen and oxygen. When these two gases mix, they make a highly explosive mixture. When you recharge a battery, you'll have to take special precautions to prevent an explosion.

The rate of gassing increases rapidly as you near the end of the charging period. At first the sulfuric acid is weak; most of the current is used up in charging the plates back to lead and lead peroxide. Later on the acid is stronger. And since the plates have been largely converted to lead and lead peroxide, there's plenty of current available for decomposing the water. And so you have to cut down the current, to keep the electrolyte from gassing too fast.

Why is rapid gassing bad? You know that the plates are porous. That increases the capacity of the battery, by providing more area for the electrolyte to work on. But the porous plates can't stand rough treatment. If gas bubbles rapidly out of the pores, it's likely to tear off particles of sponge lead from the negative plate. It's even more likely to tear off grains of lead peroxide from the positive plate. These particles fall to the bottom of the cell. Then, since the electrolyte has less material to work on, the capacity of the battery is reduced.

Here's one final equation. It summarizes the chemical action that takes place in the storage battery, during both discharge and recharging.

$$\overset{-}{Pb}+\overset{+}{PbO_2}+2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} \overset{-}{PbSO_4}+2H_2O+\overset{+}{PbSO_4}$$

The fact that it gets its energy from a storage battery gives the Mk 18 torpedo its big tactical advantage—its wakeless run. But that same fact limits its usefulness; the run is comparatively short, and not very fast Why? Because a storage battery of reasonable size and weight just can't generate enough electricity for a long run at high speed.

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AFTERBODY

The afterbody contains the motor and drive shaft, the depth and steering mechanisms, and the air system. The control mechanism assembly is so much like that of a Mk 14 or Mk 15 torpedo that there's no point in describing it here. There are only two important differences:

1. In the Mk 18 Mod 2, the gyro is of the RUN-DOWN type. After the spinning and unlocking mechanism brings it up to speed, the gyro coasts on its own momentum. Because the running time of the Mk 18 torpedo is short, the coasting gyro maintains enough speed to control the torpedo's course throughout its run. The Mk 18 therefore needs no gyro-sustaining air. There is no gyro reducer, and no fitting for supplying air through the center of the gyro top plate.

2. Because the Mk 18 torpedo is fired only from the submerged tubes of submarines, the bottom setting socket for gyro angle, and the gear train associated with it, are not present in the Mk 18.

Motor

Figure 8–11 shows the after end of the motor. You can see three lugs welded to the outer rim of the motor frame. There are three other lugs, just like them, that don't show in the picture. Bolts passed through these six lugs secure the motor to the afterbody joint ring.

The motor is a six-pole, series connected direct current unit; it develops 90 horsepower at 1,660 rpm. Figure 8–12 is a wiring diagram of the motor circuit. As you can see, the motor field windings are in series with the armature windings. This type of connection makes it a "series motor" system. The series motor has an important advantage for use in a torpedo: the motor very quickly reaches its full operating speed even when it starts under a heavy load. The full driving power of the motor is applied to the propellers at almost the instant the torpedo is fired.

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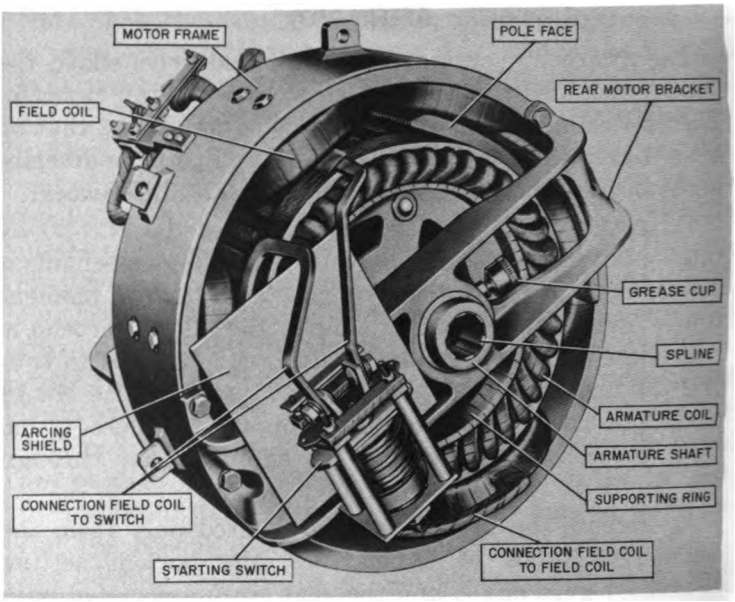

Figure 8–11.—After end of motor.

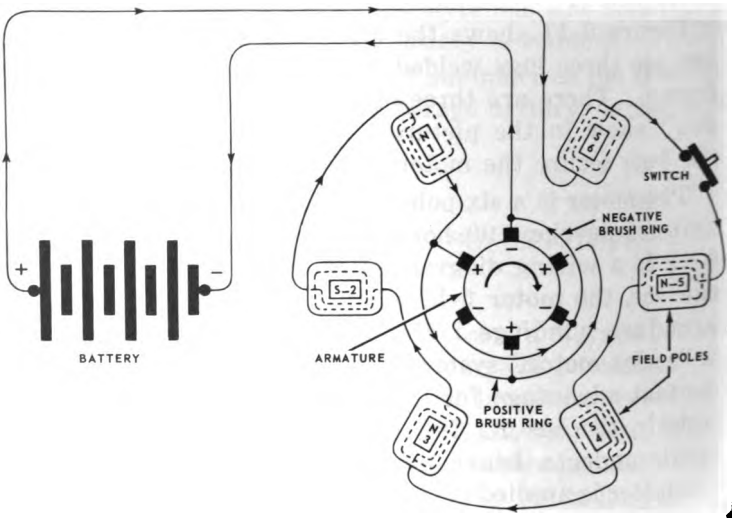

Figure 8–12.—Motor wiring diagram.

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Figure 8–13 shows how the commutator and brushes are mounted on the motor. The brushes are assembled on an insulated rocker ring in two groups of three each, spaced symmetrically around the commutator. As the armature rotates, the commutator segments reverse the connections to the armature coils at the proper instant. This reverses the direction of current through the coils as they pass under consecutive field poles, so that the motor continues to rotate. The armature, as seen from the forward end of the motor, turns clockwise.

Circuit connections are made by heavy, insulated conductors. The external connections to the motor are made with twin rubber-covered stranded cables. The use of twin cables makes it possible to use a heavy current, without sacrifice of cable flexibility. The copper connectors that extend upward from the motor starting

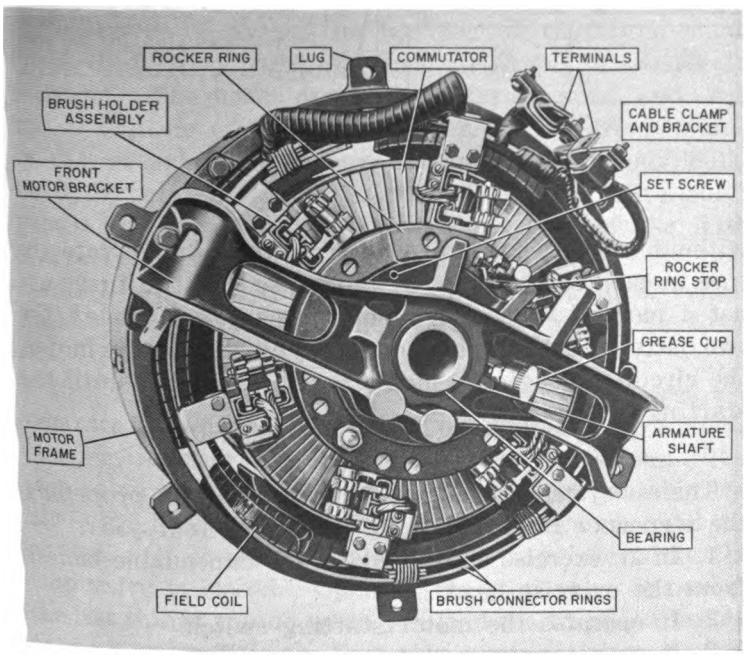

Figure 8–13.—Forward end of motor.

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switch (fig. 8–11) connect to field windings five and six, as you can see in the wiring diagram (fig. 8–12). The main drive shaft of the torpedo has splines that fit the splined armature shaft of the motor.

Electric Circuit

Figure 8–14 is a block diagram of the complete electric circuit. The dotted lines represent conducting cables. (The cables between battery and motor are actually double.) The charging circuit terminates in a socket in the afterbody, so that you can charge the battery

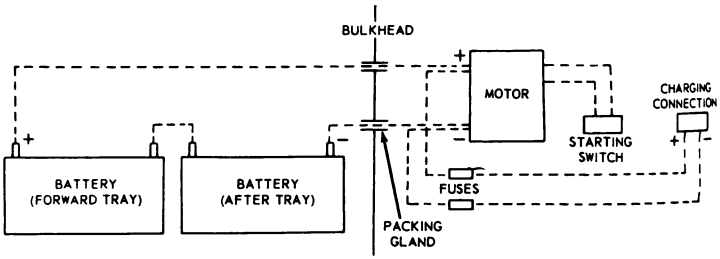

Figure 8–14.—Electric circuit.

without removing the torpedo from the tube. Note the fuse in each charging lead. Note also that the fuses are not a part of the battery-motor circuit. Although the two battery terminals are connected directly to the motor, the circuit through the motor is not completed until the starting switch closes.

Air System

The air system of the Mk 18 has no part in propelling the torpedo. It provides the power for four jobs:

1. In an exercise shot, it blows the expendable ballast from the exercise head.
2. It operates the motor starting switch.
3. It operates the gyro spinning and unlocking mechanism.

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4. Through a reducing valve, it operates the depth and steering engines.

Figure 8–15 is a block diagram of the air system.

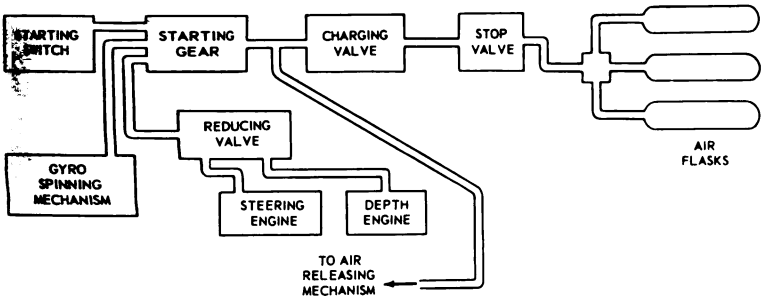

Figure 8–15.—Air system.

Figure 8–16 shows the position of the three small flasks that carry the compressed air supply of the Mk 18 torpedo. The flasks are made of forged steel, and each has a volume of 210 cubic inches. They are mounted in the afterbody, just forward of the afterbody bulkhead, by clamps and brackets. The main drive shaft passes through the opening in the center of the flask assembly. The three flasks are connected together through a cross fitting at the mouth of the upper center flask. For a war shot, the system is charged to 3,000 psi.

In a Mk 18 torpedo the stop and charging valves are separate assemblies; they are NOT contained in a single housing, as they are in the air-steam torpedoes. The stop valve (fig. 8–17) is simply a means for isolating the air in the flasks from the rest of the air system until it's needed. Of course the torpedo can't operate while the stop valve is closed. Opening the stop valve is one of the last things you do when you load the torpedo into the tube. Closing it is the first thing you do when you recover the torpedo after an exercise shot.

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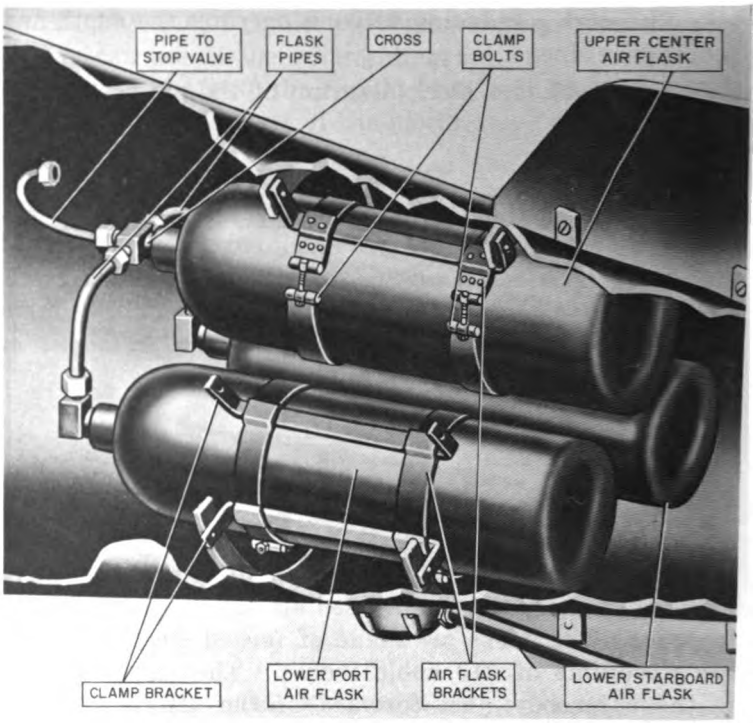

Figure 8–16.—Air flasks.

The working part of the valve is a stainless steel ball, which seats on a copper alloy insert. The threaded carrier (fig. 8–17) turns in the threads of the stop valve body. The steel ball is free to turn in any direction within the carrier, but moves up and down with it. There's a recess machined in the top of the carrier, to receive the shank of the operating spindle.

When the valve is wide open, the spindle shoulder compresses a nylon washer into grooves on the bottom of the stop valve plug. The compressed washer forms a seal, to keep air from leaking out around the spindle. So it's important, when you open the stop valve, to open it all the way.

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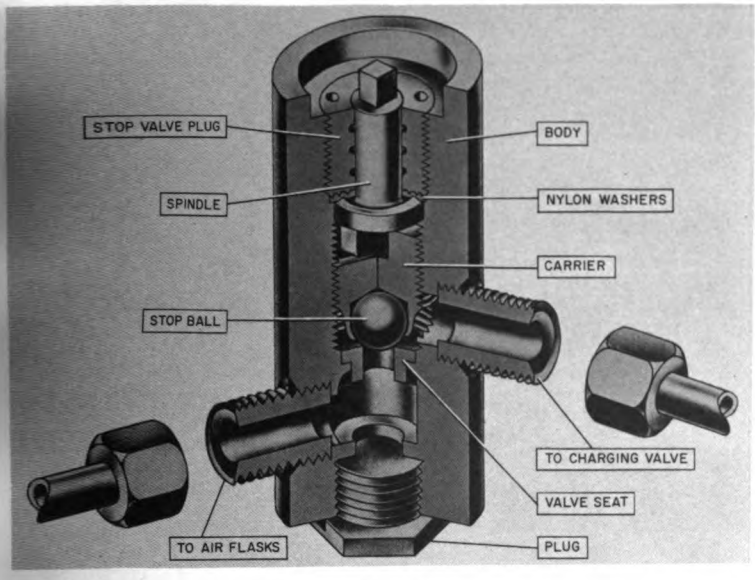

Figure 8–17.—Stop valve.

When the valve ball is firmly seated you can remove the plug, spindle, and washer, and replace them if necessary, even when the flasks are fully charged.

By means of the charging valve (fig. 8–18), you can connect the external high-pressure air line to the air system of the torpedo, to charge the three flasks. The charging valve body is welded to the afterbody shell of the torpedo. At the top of the valve body, the charging valve plug compresses a nylon gasket against its seat, to prevent leakage through the charging valve when the stop valve is open. Within the valve body, a spring-loaded check valve compresses a ring-shaped nylon gasket against its seat. (Find these parts in figure 8–18.)

The charging procedure is the same as that for an air-steam torpedo. First, you make sure that both the stop

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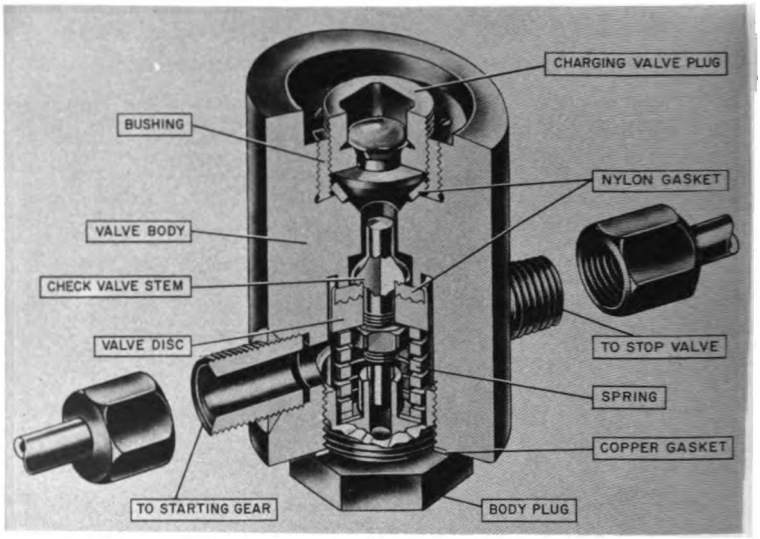

Figure 8–18.—Charging valve.

valve and the starting gear valve are closed. Then remove the charging valve plug, and insert the charging fixture. The tip of the charging fixture depresses the check valve stem, and unseats the nylon gasket of the check valve. Now, after you open the stop valve, you can charge the flasks. When they reach full pressure you close the stop valve and the valve in the exterior supply line, bleed the line, remove the charging fixture, and replace the charging valve plug.

In a Mk 18 torpedo, the starting gear and starting valve are a single assembly. When you fire the torpedo, the starting gear releases high-pressure air to the motor starting switch, the reducing valve, and the gyro spinning and unlocking mechanism. The housing of the starting gear (fig. 8–19) is an oblong body welded to a circular flange. To the nipple at the bottom of the housing, you connect the line that brings high-pressure air from the

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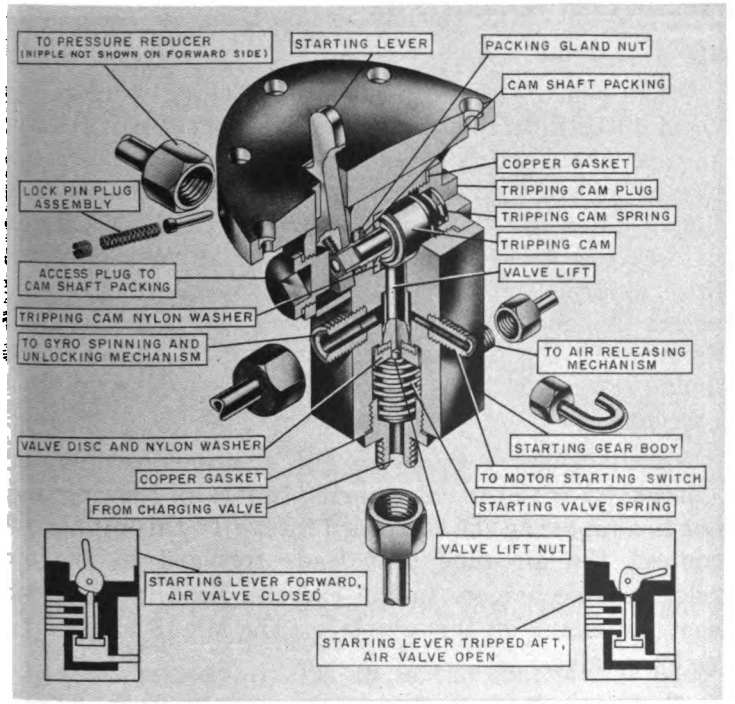

Figure 8–19.—Starting gear.

flasks (by way of the stop valve and the charging valve.) In the cavity just above this nipple, you can see the spring that holds the valve disc and its nylon washer against the valve seat. Because of the action of this spring, the valve is normally closed.

Before you fire the torpedo, you open the stop valve. High-pressure air then enters the lower cavity of the starting gear. Its pressure reinforces that of the spring, and tends to hold the valve shut.

The cavity above the valve serves as a manifold. From this cavity, nipples lead out through three of the four faces of the oblong housing: on the forward side, to the reducing valve; on the port side, to the gyro spin-

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ning and unlocking mechanism; on the after side, to the motor starting switch.

When you fire the torpedo, and it begins to move forward in the tube, the tripping latch on the top of the tube engages the starting lever and throws it aft. The motion of the starting lever rotates the cam shaft, which in turn rotates the tripping cam. The tripping cam depresses the valve lift and opens the valve. (The two little diagrams at the bottom of figure 8–19 show this action schematically.) After the starting lever is thrown aft, the spring-loaded lock pin in the mounting flange enters the lever pocket, and keeps the lever from returning to the closed position.

From the lower cavity of the starting gear housing (the cavity with the valve spring in it), an opening leads out to a nipple on the starboard face. To this nipple, you connect the air pipe that leads forward to the air-releasing mechanism in the exercise head. For a war shot, you blank off this nipple. (The Mk 18 torpedo has no blow valve.)

The operation of the steering and depth engines depends on compressed air as a power source. As you know, both these engines operate on air at only moderate pressure; the flask pressure would be much too high for them. And so the air from the starting gear passes through a reducing valve before it goes to the depth and steering engines. Figure 8–20 shows a cutaway view of the reducing valve.

High-pressure air enters the valve chamber through a nozzle. A nozzle valve, backed up by a spring, tends to close the nozzle so that no air can enter the chamber. In the bonnet at the top of the valve housing is a regulating spring, under compression. This regulating spring exerts a downward force on the bell crank; the bell crank applies this force against the nozzle valve. The force of the regulating spring overcomes that of the nozzle valve

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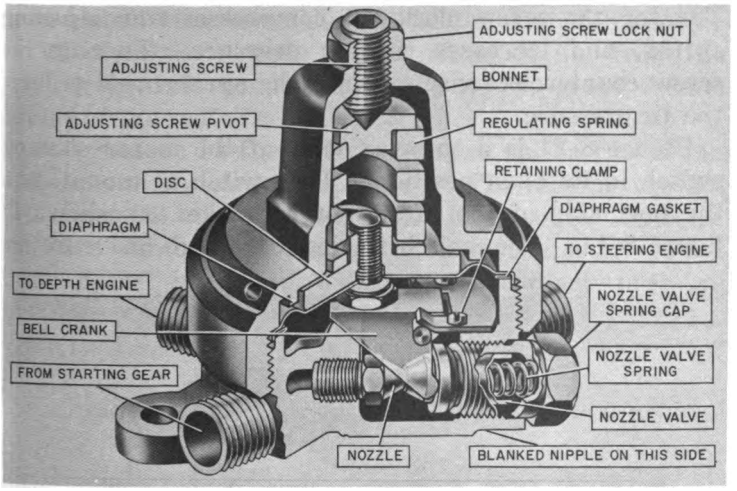

Figure 8–20.—Reducing valve.

spring; the nozzle valve opens, and compressed air enters the valve chamber through the nozzle.

As the pressure builds up in the chamber, it pushes upward against the diaphragm and disc. When the upward pressure against the diaphragm becomes greater than the downward pressure of the regulating spring, the spring is compressed again. That relieves the pressure on the bell crank, and the nozzle valve closes and cuts off the air supply. As the depth and steering engines use up the air in the chamber, its pressure falls, and the cycle repeats. Since the two engines use air constantly throughout the torpedo run, the diaphragm and nozzle valve must pulsate rapidly to maintain a constant reduced pressure.

Since the pressure of the air in the chamber depends on the compression of the regulating spring, it's obvious that you can control that pressure by adjusting the compression of the spring. To adjust the pressure of the air output, you first loosen the lock nut at the top of the valve bonnet, and then turn the adjusting screw.

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Turning the screw clockwise compresses the adjusting spring, and increases the air pressure. Turning the screw counterclockwise expands the spring, and reduces the air pressure.

Figure 8–21 is a cutaway view of the motor starting switch in its open position. The switch is mounted on the port side of the after motor bracket, as shown in figure 8–11. The switch is closed by high pressure air

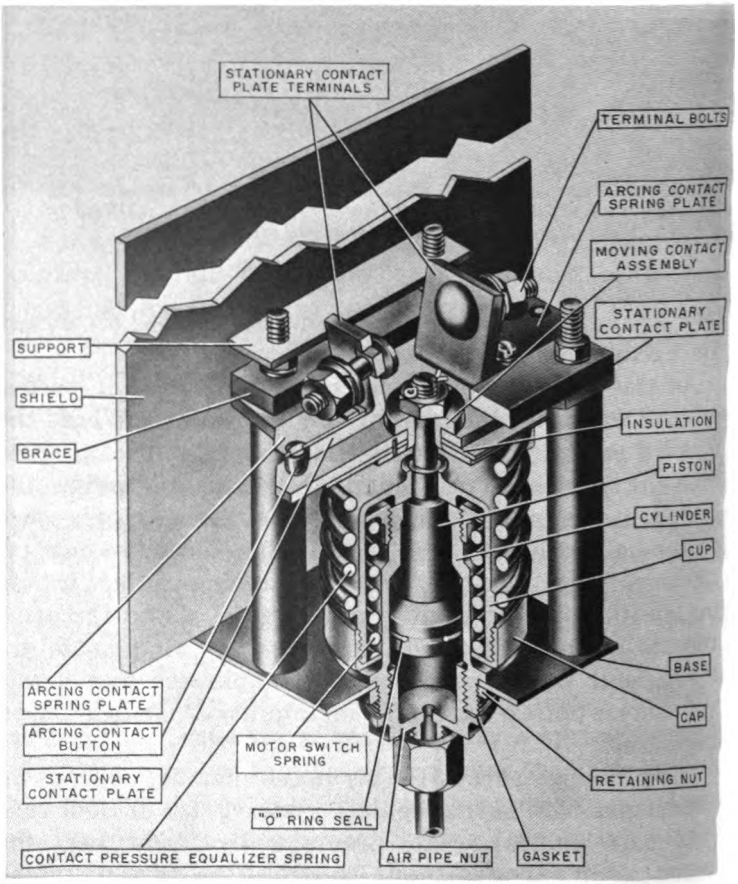

Figure 8–21.—Motor starting switch.

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from the starting valve, and this closes the battery-motor circuit when the torpedo is fired. The air line from the starting gear is connected to the air pipe nut in the bottom of the switch.

Air pressure in the switch cylinder raises the piston and the moving contact assembly. The moving contact first closes the circuit through the arcing contact buttons, and then through the stationary main contacts. (Find these parts in figure 8–21.) The contact pressure equalizer spring between the switch cup and the moving contact assembly keeps the contacts in proper alignment when the switch is closing and opening.

As long as the air pressure remains above 300 psi, the switch will remain closed. When the pressure falls to between 300 and 150 psi, the contacts are opened by an internal spring. The spring breaks the contact quickly, and thus prevents excessive arcing. The arcing contacts prevent burning of the main contacts when the switch is open.

TAIL

Figure 8–22 is a phantom view of the tail, and the after end of the afterbody. The Mk 18, like the air-steam torpedoes, has two counter-rotating propellers. But no-

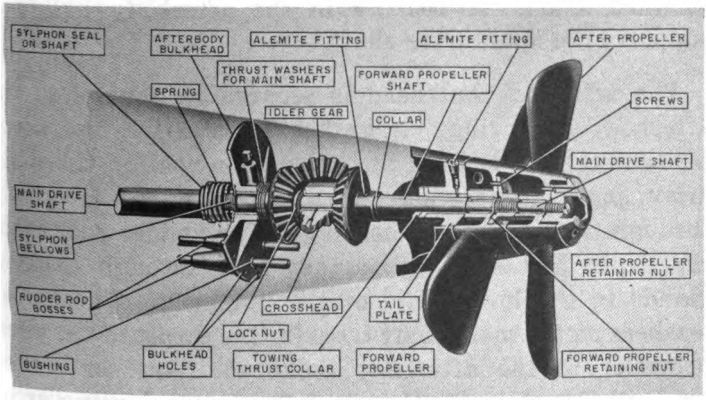

Figure 8–22.—Tail.

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tice that each propeller has only two blades, rather than four as in the air-steam torpedoes.

The after propeller is keyed to the main drive shaft, and secured by a retaining nut. The main drive shaft passes uninterrupted from the motor armature to the after propeller. The forward propeller is mounted on a shorter, hollow shaft, through which the main drive shaft passes. A bushing in each end of the hollow shaft forms a bearing for the main shaft. The gear mechanism turns the hollow shaft, and the forward propeller, in the direction opposite to that of the main shaft and the after propeller.

The forward bevel gear is keyed to the main drive shaft, and secured by a lock nut. (You can see this gear clearly in figure 8–22, just abaft the afterbody bulkhead.) The after bevel gear is keyed to the hollow shaft of the forward propeller. Two idler gears, mounted on a crosshead, transmit the driving force from one bevel gear to the other, at the same time changing the direction of rotation. (The picture, figure 8–22, shows only one of the two idler gears.)

A bushing in the tail plate forms a bearing for the forward shaft. A bearing in the afterbody bulkhead supports the main drive shaft.

The afterbody bulkhead is secured by screws to the afterbody joint ring. A gasket between the two keeps sea water from leaking in. A syphon seal on the main drive shaft keeps water from entering the afterbody through the drive shaft bearing. The rudder rods from the depth and steering engines pass through packing glands in the lower part of the bulkhead. The thrust washers on the main shaft transfer the thrust of the after propeller to the afterbody bulkhead. Another set of washers transfers the thrust of the forward propeller to the crosshead.

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MAINTENANCE AND OVERHAUL

When you perform the routine maintenance operations, or when you overhaul the torpedo, you'll be working from check lists. Nobody expects you to memorize all the steps. In fact, you're probably better off if you don't try to memorize them. So, when you take your examination for advancement in rating, you won't be asked to list the steps for disassembly and overhaul.

But these procedures should be fresh in your mind, just the same. If you haven't done so recently, now would be a good time to review chapter 9 of OP 946—especially pages 83 to 93.

SAFETY

In addition to the safety hazards you're used to—high explosives and high-pressure air—the Mk 18 has two new hazards: high voltage and acid. The special safety precautions that apply to the Mk 18 torpedo are listed in OP 946. If you aren't familiar with them, we suggest that you read them now. Pay special attention to the ones that deal with the battery.

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QUIZ

1. What is the chemical composition of the positive plates in a fully charged battery? The negative plates? The electrolyte?
2. In a completely discharged battery, what is the chemical composition of the positive plates? The negative plates? The electrolyte?
3. Why should a partly discharged battery never be allowed to stand without recharging?
4. When a battery discharges, some of the acid is changed to water. But you can't recharge it by adding more acid. Why not?
5. When you recharge a battery, why must you reduce the charging current when the battery approaches full charge?
6. Explain the function of the poppet valve.
7. Why must air from the battery space be kept out of the afterbody?
8. The cells of the Mk 2 battery are connected so that the positive and negative terminals of the battery are at opposite ends. Why?
9. Why is it necessary to ventilate the battery compartment from time to time?
10. When the valve of the starting gear opens, high-pressure air flows to three different places at once. What are they?
11. What is the function of low-pressure air from the reducing valve?
12. What are the horsepower and rpm of the motor in the Mk 18 torpedo?
13. What is the advantage of using a "series" motor for torpedo propulsion?
14. What keeps the gyro running after its spinning mechanism is disengaged?

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CHAPTER 9

MAINTENANCE OF ELECTRIC TORPEDOES

It's fairly safe to predict that, ten years from now, the duties of a Torpedoman's Mate will be a lot different from your present job. At the time this course goes to press there are thousands of air-steam torpedoes in the fleet, and most destroyers are equipped with trainable tube mounts. That picture will change, gradually but surely. Trainable tubes will be replaced by fixed tubes and torpedo launchers. The older air-steam torpedoes will be replaced by newer mods equipped with electric gyro and depth setting, or by all-electric homing torpedoes.

The Torpedoman's Mate of the future will probably need only a part of the mechanical skill that you have. On the other hand, as homing torpedoes reach the fleet in increasing numbers, Torpedoman's Mates will spend more and more time in the maintenance and repair of complex electronic circuits.

Your Qualifications for Advancement in Rating reflect this gradual change in your duties. Future revisions of the Quals will probably require an increasing knowledge of electronics. Like all the ordnance ratings, TM is increasing in scope. And the TM's must grow, along with their jobs.

In this chapter, we will remind you of what you'll need to know about electricity and electronics. We will quote a few of the Quals, and give you some suggestions on how to meet them. But your detailed information will have

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to come from other sources. You'll find the background information you need—on electricity and electronics in general—in the two Basic Training Courses: *Basic Electricity*, NavPers 10086, and *Basic Electronics*, NavPers 10087. We will describe the electric and electronic circuits of specific torpedoes in volume 2 of this course.

We suggest that, before you start volume 2, you study the two basic courses. You should have a good understanding of ALL the material in *Basic Electricity*. It's a fat book, as Training Courses go. But since you're already familiar with most of the material in it, it should be fast reading. It might be a good idea to start with the quizzes at the end of the chapters. If you find that you can answer all of the questions in any quiz, there isn't much point in reading the chapter it covers.

Basic Electronics is even fatter than *Basic Electricity*, and of course it's tougher reading. But you don't have to read all of it. Chapters 10, 11, and 14 (in the 1955 edition) deal with transmission lines, antennas, and radar. You can skip those chapters entirely. Chapters 8 and 9 are on modulation and transmitters, and chapter 12 is on radio receivers. These three chapters contain some information that you may find useful, and a great deal that you will have no use for. We suggest that you skim these three chapters. Remember what's in them, so that you can go back for further study if you have a need for this information later on.

If you're preparing for advancement to TM1, you should read all the remaining chapters of *Basic Electronics*. The Qualifications for Advancement in Rating (discussed later in this chapter) will show you which parts to study, and which parts to skim over lightly. If you're preparing for advancement to TMC, you should study all of the remaining chapters of *Basic Electronics*. (In the 1955 edition, that includes chapters 1 through 7, and 13.)

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USES OF ELECTRICITY IN TORPEDOES

Torpedoes use a large number of electric and electronic devices and circuits, to do a number of different jobs. For security reasons, we can't discuss all of the applications of electricity to torpedoes in this volume. The various applications and circuits are described in detail in volume 2 of this course. But we can summarize the principal uses, and the maintenance problems they present, in general terms.

Propulsion Batteries

The energy that propels electric torpedoes is stored in batteries. In the Mk 18 torpedo, and in a few of the homing torpedoes, these are secondary batteries, usually made up of the familiar lead-acid storage cells. The batteries of many homing torpedoes are made up of primary cells. A primary cell, as you know, can be used only once; unlike a storage cell, it can not be recharged. Primary batteries used in torpedoes are of two different types. One type consists of dry cells. The other kind is inactive as long as it remains dry, but develops its full rated voltage as soon as its cells are flooded with sea water.

Battery maintenance is usually a job for the lower rates of TM, but it may be your duty to supervise the job. Maintenance of a storage battery includes a number of different operations. Batteries must be installed in the torpedo battery compartment, or removed from it, as necessary. From time to time the voltage of individual cells, and of groups of cells, and of the battery as a whole, must be tested with a voltmeter. The specific gravity of the electrolyte must be measured with a hydrometer. The battery must be tested for shorts and grounds. Electrolyte level must be maintained by adding distilled water. It will sometimes be necessary to make new electrolyte by mixing distilled water and sulfuric acid. The battery must be recharged when the specific gravity of the electrolyte drops to a certain point.

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Of course you can't supervise this work unless you know thoroughly how it should be done. Unless you've had some recent experience with storage battery maintenance, a short review of the subject might be a good idea. You can find information in chapter 8 of this course, in chapters 1 and 2 of *Torpedoman's Mate 3 and 2*, Vol. 2, NavPers 10156, and in OP 946.

Maintenance of primary batteries is considerably simpler than that of storage batteries. There is no recharging, and no electrolyte to mix. We will discuss the primary batteries in volume 2 of this course.

In supervising any battery maintenance work, enforcing the safety precautions is one of your most important duties. You must not only keep the safety precautions constantly in mind, but you must see that the men working under your supervision keep them constantly in mind. You don't need to be told that a torpedo battery can deliver enough current to cause a fatal shock. The sulfuric acid used to mix electrolyte can cause serious burns, and, if it gets in the eyes, blindness. You'll find a review of safety precautions, and of first-aid treatment for electric shock and acid burns, in chapter 12 of *Torpedoman's Mate 3&2*, Vol. 2.

Motors and Dynamotors

Torpedo Mk 18, and all of the homing torpedoes now in production, are propelled by electric motors. Small electric motors are used at various places in several types of torpedoes, to do some of the small jobs done by compressed air in the air-steam types. And, as you probably know, a small electric motor is a part of each of the servo mechanisms used for electric gyro and depth setting.

Dynamotors are not often used in torpedoes, but the Qualifications for Advancement in Rating mention dynamotor maintenance as a requirement for TM2. A dynamotor is a combination motor and generator. The

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motor part is driven by a high-current low-voltage DC source. The generator output is high-voltage pulsating DC. After filtering, this high-voltage output can be used as a power supply for electronic circuits.

Maintenance of motors and dynamotors is usually a job for a TM3 or TM2. You will almost certainly have to supervise some work of this kind. *Basic Electricity*, NavPers 10086, covers DC generators and motors in chapters 10 and 11. Dynamotors are discussed in chapter 3 of *Basic Electronics*, NavPers 10087. These two courses cover only the basic theory; they give no information on maintenance. The best source of maintenance instructions is the OP that describes the torpedo you're working on. There is some useful information on the maintenance and trouble-shooting of motors and generators in Chapter 10 of *Electrician's Mate* 3, NavPers 10548–A.

Synchros and Servomechanisms

In all of the electrically-set torpedoes, servo-mechanisms are used to set gyro angle and depth. A servo-mechanism includes a servo motor and one or more synchros. At present, maintenance and repair of these devices is a job for a TM 1 or C. Maintenance consists of testing, cleaning, and adjusting, and if necessary replacing a faulty unit with a new one. A thorough test requires the use of special test instruments. These instruments make it possible to send electrical inputs, corresponding to various depth and gyro-angle orders, into the servo-mechanism, and to measure its response. The adjustment of a servo-mechanism consists of two separate steps. You will first adjust the gear train, or other device driven by the servo motor, to its mechanical "zero" position. You will then adjust the synchros to bring them to their electrical "zero".

You will find basic information on synchros, and a short discussion of servomechanisms, in chapter 17 of

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Basic Electricity. In volume 2 of this course we will describe the specific servo-mechanisms and circuits of various torpedoes, and tell you where to find the maintenance checkoff lists.

Electronic Circuits

Several circuits of a homing torpedo, in addition to those directly associated with the homing feature, are electronic. Testing, alining, and adjusting these circuits, and replacing defective parts, is at present a job for a TM 1. Testing is relatively simple after you have learned to use the test instruments. It consists in making a prescribed input to the circuit, and measuring its response at various points. It is possible to test, align, and adjust many electronic circuits simply by following detailed checkoff lists. But of course the more you know about the principles the circuits are based on, the faster and more effective your work will be. The background information you will need is in *Basic Electricity* and *Basic Electronics*. We will describe specific torpedo electronic circuits in volume 2.

Circuit tracing and trouble shooting of electronic circuits is a job for a TMC. It would be impossible to make a checkoff list that would cover all possible failures. Trouble shooting requires a thorough understanding of the theory and principles of every part of the circuit.

ELECTRIC AND ELECTRONIC QUALS

Your Qualifications for Advancement in Rating (Appendix II of this book) list a number of requirements in electricity and electronics. We will quote the quals for TM 1&C, and make a few suggestions for meeting them. You should bear in mind that when you take your written examination for advancement in rating, you may have to answer questions about the work of the lower rates. You have to know everything a TM3 or 2 knows, but you have to know it better. If you aren't sure of yourself, look up the TM 3&2 quals in Appendix II. If

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you're rusty on any of these subjects, review them as necessary in *Basic Electricity*.

Qualifications for TM 1

101.6 *Identify electronic component symbols.*

201.4 *Identification of standard electronic parts symbols used in schematic drawings.*

Chapter 12 of *Blueprint Reading*, NavPers 10077, deals briefly with electric schematic diagrams, but it doesn't cover all the symbols you will have to recognize. Figure 9–1 is a schematic diagram of a simple radio receiver, which shows the actual appearance of the principal parts. The parts pictured at the top are, from left to right:

Antenna coil (RF transformer).

Variable capacitor.

Vacuum tube (pentode).

IF transformer. (A part of the shield can has been cut away; an IF transformer is nearly always completely enclosed.)

Volume control potentiometer.

Vacuum tube (triode with two diodes).

Earphones.

The part shown at the left center of the diagram is a fixed tubular capacitor. The three parts at the right center are, from top to bottom, a carbon resistor, a fixed tubular capacitor, and an AF choke coil.

The parts at the bottom of the diagram are, from left to right:

Carbon resistor.

Fixed mica capacitor.

Variable mica capacitor.

RF transformer.

RF choke coil.

Power transformer.

Vacuum tube (double diode).

Capacitor (electrolytic, can type).

Wire-wound resistor, tapped.

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It's obvious that you can't always guess what a part will look like from its symbol in a schematic diagram. Vacuum tubes have a wide variety of shapes and sizes. Some have metal shells; others have glass shells. Relays and other components are sometimes enclosed in metal shells and provided with plug-in bases, so that they look like vacuum tubes. The symbol for a fixed capacitor doesn't give you any idea of its appearance. It may be of the can type, or tubular paper, or tubular plastic, or of the flat mica type; or it may be sealed in a rectangular metal can. Carbon resistors and wire-wound resistors have the same symbol. Power transformers are of several different types. They may resemble the one shown in figure 9–1, or they may look more like the choke coil shown in the same figure; some transformers are

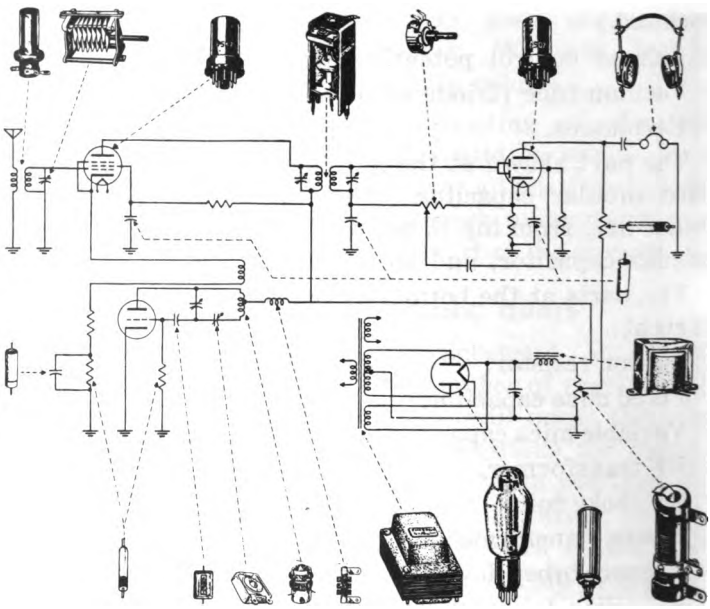

Figure 9–1.—Circuit components and symbols.

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completely enclosed, with their leads coming out through the bottom.

If you have a piece of electronic equipment, and a schematic diagram of it, how can you identify the parts and trace the circuit? This job becomes easier with a little experience. In the beginning, ask for help when you need it. You will quickly learn to recognize most electronic parts, in all their various forms. In many schematic diagrams of electronic circuits, the parts are numbered. For example, resistors are numbered R1, R2, etc.; capacitors are C1, C2, etc.; transformers are T1, T2, etc. You will often find a parts list printed at the bottom of such diagrams. The list names the part, and states its value (in ohms, microfarads, etc.) It also states the type of component (wire-wound or carbon resistor, mica or paper condenser, etc.) In many cases the list will state the manufacturer and type number of the principal parts. On major parts such as AF chokes, transformers, relays, electrolytic capacitors, etc., the manufacturer will usually stamp his type number, even if he gives no other information. The type number of a vacuum tube is always printed on it—usually on the side of the shell—but sometimes on the top of the shell and occasionally on the tube base. (This number will sometimes be hard to read, especially on glass-shelled tubes that have been handled a lot.)

In schematic diagrams such as figure 9–1, wires are shown connected to the various elements of the vacuum tubes. In some drawings you will find numbers that show the tube socket connections to which the various wires are soldered. But with most drawings you will have to get this information for yourself. You can find a diagram of any vacuum tube, showing the socket connections, in the appropriate tube manual.

Figure 9–2 shows the pin arrangement and socket connections for several common electron tubes. The circles at the top of the picture represent several types of

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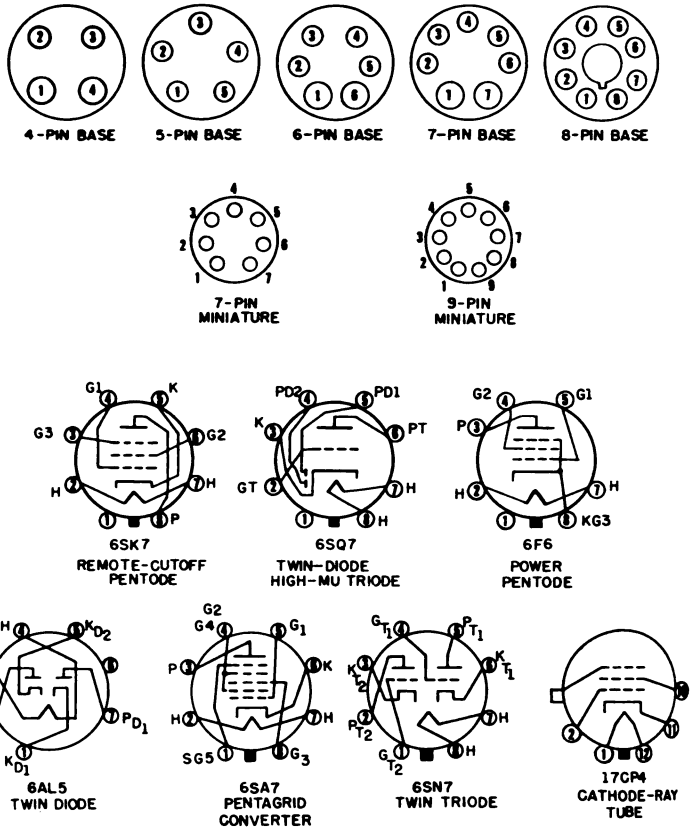

Figure 9–2.—Common electron tubes and tube bases.

tube bases, and show how the tube pins and socket connections are numbered. In this figure, you are looking at the tube bases (or sockets) from the BOTTOM. The numbers run clockwise. This is the position in which you ordinarily view a tube socket—especially when you're tracing a circuit under the chassis, or making a connection. If you use an ohmmeter to test a heater filament for continuity, you will normally hold the tube upside down. But you may sometimes remove a tube

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from its socket in order to measure the voltage at various socket connections from the top. Remember that when you view the socket from the top, the connections are numbered COUNTERclockwise.

In counting tube pins or socket connections, of course you have to know where to start. In the 4-pin, 6-pin, and 7-pin bases (top of fig. 9–2), two of the pins are larger than any of the others. Pin number 1 is the most clockwise of this pair. In the 5-pin base, the distance from pin 3 to pin 2, and from pin 3 to pin 4, is greater than the spacing of the other pins, so that pin 3 stands more or less alone. With the 8-pin (octal) base, pin 1 is the first pin clockwise of the key on the tube base (and socket connection 1 is immediately clockwise of the key slot in the socket.) In the two miniature sockets there is a space (considerably larger than indicated in figure 9–2) between the first and last pins. Pin one is the first pin clockwise of this space. (This is true, of course, only when you're looking at the tube base or socket from the bottom.)

The first four tube bases shown in figure 9–2 are obsolescent. In new equipment most tubes (other than cathode ray tubes) are made to fit octal or miniature sockets.

101.8 *Interpret electronic wiring and circuit diagrams found in equipment instruction books.* To "interpret" a wiring diagram, you must be able to recognize the parts and be able to tell how they are wired together. This is easy. But to interpret a schematic diagram is somewhat harder. First, of course, you must be able to recognize the symbols. Second, you should be able to form a fairly clear idea, just by studying the diagram, of what the circuit does and how it operates. The complete circuit of an electronic device looks complicated. But, with a little study, you can see that it is made up of a number of simpler circuits, and most of these are of standard types. You should be able to recognize these standard circuits,

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such as power supply, filter, a-c and d-c amplifier, oscillator, etc., when you see them in the diagrams. You should have a clear idea of what these circuits are designed to do, and how they do it. This is a part of the basic knowledge that will come from your study of the *Basic Electronics* course.

102.19 *Perform all electrical and electronic circuit tests of a torpedo; replace parts and adjust and aline components on own ship or station.*

Checkoff lists for all the circuit tests will be available to you, either from the OP's or from other sources. The proper use of these lists requires that you have a basic understanding of the circuit you're testing, and some skill in using the test instruments. Replacing a defective part (after a TMC has shown you which part to replace) is simply a matter of unsoldering the leads, removing the old part and installing the new one, and cutting and soldering the leads of the new part in the proper places. Variable resistors, capacitors, and inductors are almost the only adjustable parts of electronic circuits. These parts must be adjusted to produce a proper voltage or current at a given point, or to tune an amplifier or oscillator to its proper frequency, or to adjust an R-C circuit to the proper time constant. The checkoff lists will identify the various test points, and tell you what voltage, frequency, or other quantity should appear at that point. A tuned amplifier is "alined" by adjusting it to be most sensitive at the desired frequency. The last part of this qual—"on own ship or station"—points out that you will NOT be expected to develop a skill in testing and adjusting circuits you've had no chance to work with.

202.21 *Function of transducers, servo systems, amplifiers, relay control circuits, and vibrators in torpedo electronic systems.*

A transducer is a device that changes one form of energy into another. For example, a loudspeaker and a microphone are both transducers. A loudspeaker

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changes electric impulses into sound; a microphone changes sound into electric impulses. As far as the TM is concerned, a transducer is a hydrophone. A hydrophone serves the purpose of a speaker or a microphone, but it is especially designed to produce sound waves in water, or to pick up sound waves from water and change them to electrical impulses. Active acoustic torpedoes use hydrophones to send out pulses of sound, and to detect echoes returning from the target. Passive acoustic torpedoes use hydrophones to detect propeller and machinery noises coming from the target.

The basic principles of servo systems and the other items mentioned in this qual are covered briefly in the *Basic Electronics* text. We will describe their specific applications to torpedoes in volume 2 of this course.

202.22 *Calculate phase angle and impedance in a series circuit and a parallel circuit, each containing not more than four elements.*

This requires an understanding of the basic principles of a-c electricity, and the effect of inductors and capacitors on phase angle and current. These subjects are covered in chapters 12 and 13 of *Basic Electricity.* To understand these two chapters and to solve the problems, you will need some skill in algebra and elementary trigonometry. If you find that you can't handle the math easily, go back to volume 2 of *Mathematics,* NavPers 10070, for a review.

202.23. *Safety features of a pre-enabling circuit.*

This qual refers to the ACR, SC, and depth limit circuits of homing torpedoes. These circuits are discussed briefly in chapter 11 of *Torpedoman's Mate 3&2,* volume 2, NavPers 10156. We will describe them in more detail in volume 2 of this course.

Qualifications for TMC

102.26. *Make authorized tests and repairs to torpedo exploder mechanism test equipment (multimeter type circuits).*

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A multimeter, as you surely know, is a combination voltmeter, ohmmeter, and ammeter. As test instruments go, it's fairly simple. It contains a meter, a number of resistors, one or more switches, a small rheostat, and in some instruments a selenium rectifier. In the OP's that describe the exploders (exploder Mk 9 and higher mark numbers), you'll find all the information you need to maintain and calibrate the test equipment.

102.27. *Trace electronic circuits and analyze circuit failures of a torpedo on own ship or station.*

Tracing a circuit consists of comparing the actual equipment with its schematic diagram, and following the flow of a current or a signal from one component to another, throughout the system. The components are usually easy to identify (for a TMC, that is). Following the circuit from one component to another is sometimes difficult; the wiring is often hidden by other components, or the wires may be tied together in cables. In these cases you'll find an ohmmeter helpful in following the circuit. (Use it only when the equipment is de-energized, of course.)

The analysis of circuit failures (i.e. circuit trouble-shooting) often takes skillful detective work. TM's of the lower rates will usually perform the circuit test, to determine whether a circuit is working properly. But if the circuit is not working, it will be your job to find the trouble, and to indicate the part that must be replaced or adjusted.

Successful trouble shooting is based on knowledge, understanding, and experience. Before you can find out what's wrong with a faulty circuit, you have to know what that circuit is supposed to do when it's working properly. It is often helpful to think of a given part of a circuit in terms of its inputs and outputs. For example, consider a pentode operating as an a-c amplifier. Its inputs include a ground connection, plate and screen voltages, a heater voltage, an a-c signal on its grid, and

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in some circuits a bias voltage. Its output is an amplified a-c signal on its plate. If you suspect that this pentode circuit is faulty, a logical first step is to check the a-c signal input to its grid. If this signal is not present, the trouble is obviously somewhere else. If the input is correct, check the output. If the output is incorrect, pull the tube and test it on the tube tester. If the tube is satisfactory replace it, and check the other inputs, such as plate voltage, ground connections, bias voltage, etc. If these are all correct, check the value of the circuit resistances, and look for open or shorted coupling and bypass capacitors. If these parts are satisfactory you've eliminated every possibility but one—an open or faulty solder joint at one of the tube socket connections.

It's safe to say that every electronic circuit has an output of some kind. You can test this output if you know what it's supposed to be. Most circuits receive one or more input signals, and these can be tested if you know what they ought to be. (A few circuits—oscillators, for example—will have an output but no input signal). In many cases the normal test procedure will show that the trouble is in some small unit of the circuit, such as the pentode amplifier stage considered above.

But sometimes you will have no clue as to where the trouble lies; all you'll know is that the circuit as a whole doesn't work. Your best best then is usually to trace the signal through the circuit, one stage at a time, until you come to the faulty unit. You won't be expected to repair radios, but a radio receiver is a good example to illustrate the principle of signal tracing. The input to a radio is an RF signal on its antenna. The output is a sound from its speaker. If there is no output, you might use an RF signal generator to supply an input signal to the antenna. You could then use an oscilloscope to trace the signal through the receiver. You can follow the signal from one unit to the next, until you find a component that has a proper input but an improper output. You have then

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found the cause of the trouble—or at least one of the causes.

In general, electronic circuit troubles are of three kinds. First, faulty components. Vacuum tube filaments, transformer windings, etc., sometimes burn out. Vacuum tube performance often falls off as the tube ages, even if its filament is intact. Capacitors and resistors sometimes change in value with age, especially in the presence of heat, moisture, or vibration.

Second, faulty adjustments. This includes improper settings of variable resistors, potentiometers, capacitors, and inductors.

Finally, faulty connections. This includes broken wires (although this is rather rare), wires disconnected from their terminals, or connected to the wrong terminals, open or poor solder joints, and short circuits.

We can sum up by saying that successful trouble shooting depends on knowing two things. First, you must know what the circuit as a whole is supposed to do, and what each part of it is supposed to do. Second, you must know how to use the test instruments to determine which part of the circuit is not doing what it's supposed to.

202.26. *Application of resistors, potentiometers, capacitors, transformers, and vacuum tubes in oscillating, switching, detector, automatic volume control, rectifier, feedback network, and d-c amplifier and a-c amplifier circuits.*

This is just about the most comprehensive qual in the whole quals manual. It covers practically the whole field of basic electronics, except radio transmission and radar. The best way to meet this qual is to study the training course *Basic Electronics*, chapters 1 through 7, and chapter 13.

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QUIZ

1. What are your best sources of basic information on electricity and electronics?
2. What operations are involved in the maintenance of lead-acid type torpedo batteries?
3. In battery maintenance, safety precautions are necessary to prevent two different kinds of injuries. What are they?
4. What is the principal use of a dynamotor?
5. What is the principal use of servomechanisms in torpedoes?
6. How can you test a torpedo servomechanism?
7. Turn back to figure 9–1, and identify all of the parts and symbols shown in the diagram, without referring to the text.
8. How can you use a schematic diagram to trace an electronic circuit and identify its parts?
9. In which direction are tube pins and socket connections numbered (looking from the bottom)?
10. Which is pin 1 of an octal-base tube? Of a 7-pin or 9-pin miniature tube?
11. What must you do to "interpret" a wiring diagram?
12. What are the principal "adjustable" parts of electronic circuits?
13. What is a transducer?
14. What kind of transducer is used in torpedoes?
15. What kinds of math will you need to solve problems involving phase angle and impedance?
16. Who is responsible for finding the exact cause of trouble in a torpedo electronic circuit that doesn't work properly?
17. Tell briefly how you can use the signal-tracing technique to locate a faulty unit in an electronic circuit.

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APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

INTRODUCTION

1. Because you need a comprehensive knowledge of all phases of torpedo maintenance and repair, so that you can effectively supervise this work.
2. Chemical torpedoes, homing torpedoes, and electric torpedo setting mechanisms.
3. The torpedo-gyro setter.
4. In *Torpedoman's Mate 3&2*, Volume 2.
5. The torpedo-tube captain.
6. He will be your immediate supervisor, and you will carry out his policies in supervision of the torpedo crew; in an emergency you may have to take over his duties.
7. Preparing the torpedo repair schedule; supervising repair work; completing reports; supervising maintenance of repair shop equipment.
8. Only when specifically authorized to do so by BuOrd, usually by means of an OrdAlt.

CHAPTER 2

PAPER WORK

1. The reports regularly submitted by the gunnery departments of ships in the fleet.
2. Reports; records; requisitions and letters of request.
3. In the *Bureau of Supplies and Accounts Manual.*
4. Producer logistics: getting materials from their sources; consumer logistics: delivering these materials to the user.
5. The Bureau of Ordnance.
6. Supplies are consumed in use; equipage is not.

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7. These are complete lists of all the equipage and consumable supplies to be carried on Navy vessels.

8. The Ordnance Stock Office, and the Naval Torpedo Station at Newport.

9. By requisition, and by letter of request.

10. Your commanding officer, the type commander, and, except in grave emergency, the cognizant bureau.

11. Stub Requisition, and Request for Issue or Turn-in.

12. By presenting a stub requisition signed by your department head.

13. A Stub Requisition must be filled out and forwarded to the supply officer, so that he can order a replacement.

14. Get a signed receipt for it.

15. A survey is a formal means for reporting material that is lost or damaged beyond repair, so that it can be removed from the ship's records.

16. A detailed account of the activities of the torpedo crew and its ordnance.

17. A life history of an individual torpedo. It goes with the torpedo from its manufacture until its final disposition. The book is then forwarded to BuOrd.

18. The CSMP, or Current Ship's Maintenance Project, is a record of alterations and repairs to be performed at some future time, when the ship is inactivated.

19. The commandant of the shipyard effecting the OrdAlt.

CHAPTER 3

REVIEW OF THE AIR-STEAM TORPEDO

1. If you've been specializing in the overhaul of one part of the torpedo, you may have forgotten a few things about the rest of it. From now on you'll be supervising more and more men, and you must be prepared to answer their questions about all parts of the torpedo.

2. For a general review of basic principles, see the training course *Torpedoman's Mate 3 & 2*, in two volumes, NavPers 10155 and 10156. For specific details, see the OP's.

3. Steam turbine engines, and electric motors.

4. Mks 13, 14, 15, and 23.

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5. Mk 13.

6. Two speeds: Mk 14. Three speeds: Mk 15.

7. The Mk 23 torpedo is like the Mk 14, except that it operates only in high speed.

8. Mk 16. Navol is a strong solution of hydrogen peroxide in water.

9. The navol torpedo is nearly wakeless. It has long range and high speed, and carries a heavy payload of explosive.

10. The air-flask and midship sections are permanently joined. The afterbody and tail are joined for shipment.

11. War head, exercise head, war-exercise head.

12. Headlight, torch pot, pinger.

13. To add extra weight below the torpedo centerline, and thus serve as ballast.

14. To arm itself during the first part of the torpedo run. (It must be inoperable before arming, but ready to function immediately after arming.) To detonate the main charge of explosive when the torpedo reaches its target.

15. To permit the operation of magnetic influence exploders.

16. When the torpedo reaches the end of an exercise run, the air-releasing mechanism releases air into the exercise head, to expel the liquid ballast.

17. It permits liquid ballast to be blown out of the exercise head, but keeps sea water from entering.

18. The blow valve, at the forward end of the air flask, makes it possible to open or close the line that leads to the air-releasing mechanism in the exercise head. For a war shot, the blow valve must be closed.

19. Through the small removable bulkhead at the forward end.

20. The water compartment forms the after end of the air-flask section. The fuel flask is inside the water compartment.

21. Two air-check valves, fuel-check valve, water-check valve, stop valve, starting valve.

22. To prevent overheating of the combustion flask and its related parts.

23. Restriction valve, nozzle valve, side gears. The Mk 14 torpedo has no side gears.

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24. To insure thorough mixing of air, fuel, and water.

25. The vertical rudders steer the torpedo to right or left; the horizontal rudders steer it up or down.

26. Into the hollow tail section, through the perforations in the propeller sleeves, and out through the afterpropeller sleeve.

27. 2,800 psi.

28. Igniter: 450 psi. (It operates when the pressure inside it builds up to about 250 psi.) Gyro spinning mechanism: 2,800 psi. Gyro sustaining air: 125 psi. Depth and steering engines: 450 psi.

29. The restriction valve.

30. By venting the line from the starting valve, it allows the starting valve to open and supply air to the other mechanisms.

31. It provides a controlled leak-off for the air in the control chamber, and thus determines the pressure of the air that passes through the reducing valve.

32. The preheater is a double loop of pipe in the path of the turbine exhaust gases. It preheats the air before it reaches the reducing valve, and thus improves the operation of the valve.

33. They keep fuel and water from leaking into the reducing valve and combustion flask before the torpedo is fired.

34. To remove any dirt that might clog the passages of the restriction valve.

35. Turbines, turbine spindles, turbine pinions, main drive gears, bevel pinions, bevel gears, drive shafts, propeller sleeves, propeller hubs, and propellers.

36. They support the turbine spindle casing, the turbine top bearing holder, the crosshead, and the strut that carries the bearings for the forward propeller shaft.

37. By a spray of oil thrown out by the bevel gears and bevel pinions.

38. The Mk 13 has a piston-type oil pump; the others have gear-type pumps. The pump is driven by a gear on the lower end of the second turbine spindle.

39. It relays steering orders from the gyro to the steering engine. It takes power from a gear on the outer propeller shaft.

40. It works with the diaphragm to control the rate at which the torpedo changes depth.

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CHAPTER 4

REVIEW OF FIRING AND RECOVERY

1. In volume 2 of this course.
2. So that this information can be used in local control in the event of a director casualty.
3. He depresses the firing key when ordered to do so by the torpedo officer.
4. After an exercise shot, the mount is usually trained to 000°. After a war shot it is usually left trained out, so that firing can be resumed quickly if necessary.
5. At the breech end of the tubes.
6. Supervision of personnel in the torpedo room, and operation of the blow-and-vent manifold.
7. The emergency stop valve must be closed. The drain valve operator is responsible for this action.
8. The valve is refilled with clean fresh water.
9. He should inform the conning tower, then switch to hand control and match the readings manually.
10. Zero for forward tubes; 180° for stern tubes.
11. The man between the tubes.
12. In the latest revision of OP 1085.
13. The director output is sight angle; the output of the TDC is gyro angle.
14. From the lee side, to keep the boat from setting down on the torpedo.
15. The recovery boat must get out from under.
16. To prevent deterioration. Check-off lists are given in the OP for each torpedo.

CHAPTER 5

TORPEDO FIRE CONTROL

1. In *Torpedoman's Mate 3&2, Vol. 2*, NavPers 10156, and in OP 1586.
2. Sight angle *Ds* (or, after the corrections are applied, corrected sight angle *Dsk*).

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3. Sine of the angle $= \frac{\text{side opposite}}{\text{hypotenuse}}$

4. Look it up in a table of trigonometric functions.

5. Look it up in a table of trigonometric functions.

6. The target angle *A* is the angle between the fore-and-aft axis of the target and the line of sight (or the relative bearing of own ship as seen from the target.) It's measured clockwise from the target's bow to the line of sight.

7. Target speed, target angle, and torpedo speed.

8. $A = Co + Br + 180° - Ct$

9. The graphic presentation of any quantity that has both size and direction.

10. *Xt*—target deflection—the motion of the target across the line of sight. *Xto*—torpedo deflection—the motion of the torpedo across the line of sight.

11. They are identical.

12. $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

13. Because the sight angle is determined by measuring it with a protractor, rather than by calculation.

14. Latitude correction *Kla* and intercept offset *Osi*.

15. It is not practicable to change the balance nut setting every time the ship changes latitude.

16. Intercept offset *Osi*, determined by the commanding officer, is intended to compensate for the effect of expected target maneuvers.

17. *Btr* is the angle between the fore-and-aft axis of the target and the final track of the torpedo, measured clockwise from the target's bow.

18. 90° or 270°, because the target ship is then squarely broadside when the torpedo arrives.

19. Gyro angle *G*.

20. The true torpedo course is equal to gyro angle added to own ship's course.

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CHAPTER 6

GYROS

1. Rigidity in space, and precession.
2. Inertia.
3. Because the earth itself is moving in space.
4. For all practical purposes, the direction of a star from any point on the earth is a fixed direction in space.
5. The gyro will not creep at all. (Or, to be very exact, it will creep along an arc of an extremely small circle.)
6. Horizontal (or left-and-right) and vertical (or up-and-down).
7. Horizontal creep.
8. The gyro creeps to the right; move the balance nut IN.
9. The gyro axis moves in a direction at a right angle to that of the applied force.
10. The balance nut applies a force in a vertical plane. The gyro will undergo precession, and move in a direction at a right angle to that of the applied force. The balance nut can therefore cause the gyro axis to precess to left or right. If the balance nut is properly positioned, the precession will cancel the horizontal creep.
11. Gyroscope Mk 12 Mod 3.
12. The after face of the after bearing has a socket to engage the centering pin.
13. It engages a similar gear on the shaft of the spinning and unlocking mechanism.
14. It balances the after spur gear, in both weight and air resistance.
15. A gyro with three degrees of freedom can turn on any of three axes, each of which is perpendicular to the other two.
16. The outer gimbal turns on a vertical axis; the inner gimbal turns on an athwartship axis; the gyro wheel turns on a fore-and-aft axis.
17. Low pressure air enters through the center of the top bearing, passes through channels in the outer gimbal ring, through the side bearing sleeves and the ducts of the inner gimbal ring, through the side bearing sleeves and the ducts of the inner

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gimbal, and strikes the buckets of the gyro wheel. It exhausts into the gyro pot through openings in the top and bottom of both ends of the inner gimbal.

18. Horizontal creep turns the outer gimbal, which carries the cam plate along with it; vertical creep moves only the inner gimbal, without changing the position of the cam plate.

CHAPTER 7

CONTACT TORPEDO EXPLODERS

1. a. Mk 6.
   b. Mk 11.
   c. Mk 14.
   d. Mk 11.
   e. Mk 6.
   f. Mk 14.
   g. Mk 6.
   h. Mk 6, 14.
   i. Mk 11.
   j. Mk 11.
   k. Mk 6.
   l. Mk 14.
   m. Mk 11.
   n. Mk 11.
   o. Mk 14.
   p. Mk 11.
   q. Mk 6.
   r. Mk 6, 11, 14.
   s. Mk 14.
   t. Mk 6, 11, 14.
   u. Mk 11.
   v. Mk 6, 14.
   w. Mk 6.
   x. Mk 11, 14.
   y. Mk 6.
   z. Mk 14.
2. a. Mk 6.
   b. Mk 6, 14.
   c. Mk 6, 14.
   d. Mk 11.
   e. Mk 6, 14.
   f. Mk 11.
   g. Mk 6.

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h. Mk 11.
i. Mk 6.
j. Mk 6, 11, 14.
k. Mk 6, 14.
l. Mk 11.
m. Mk 11.
n. Mk 11.
o. Mk 14.
p. Mk 6.
q. Mk 11.
r. Mk 11.
s. Mk 11.
t. Mk 11.
u. Mk 6.
v. Mk 14.
w. Mk 6, 14.
x. Mk 6, 14.
y. Mk 11.
z. All exploders.

CHAPTER 8

ELECTRIC TORPEDOES

1. The positive plates are lead peroxide; the negative plates are lead; the electrolyte is dilute sulfuric acid.

2. Both positive and negative plates are lead sulfate. The electrolyte is very dilute sulfuric acid.

3. The plates of a partially charged battery will gradually become sulfated; they will be covered by an abnormal form of lead sulfate that resists the action of the electrolyte.

4. Adding more acid will do nothing to change the lead sulfate on the plates back to lead peroxide and lead.

5. To control gassing. Gassing increases as the battery approaches a full charge, and excessive gassing will damage the plates.

6. It allows excessive air pressure in the afterbody to exhaust into the battery space; at the same time, it keeps gases of the battery space from entering the afterbody.

7. Air in the battery space is likely to contain hydrogen. If it entered the afterbody, the hydrogen might be ignited by a spark from the motor switch or brushes.

8. To prevent high voltage between adjacent cell connectors.

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9. The hydrogen eliminator works by combining the hydrogen with oxygen. When it has used up the oxygen in the battery space, it can no longer function.

10. The motor-starting switch, the gyro spinning mechanism, and the reducing valve.

11. It operates the depth and steering engines.

12. 90 horsepower at 1,660 rpm.

13. It quickly reaches full speed, even when starting under a heavy load.

14. The gyro coasts on its own momentum.

CHAPTER 9

MAINTENANCE OF ELECTRIC TORPEDOES

1. Navy Training Courses *Basic Electricity*, NavPers 10086, and *Basic Electronics*, NavPers 10087.

2. Installing and removing, testing voltage and specific gravity, filling, preparing electrolyte, testing for shorts and grounds, and recharging.

3. Electric shock and acid burns.

4. To provide high-voltage d-c for an electronic power supply.

5. Servomechanisms are used for electric setting of gyro angle and depth.

6. By using special test instruments, you can make electrical inputs to the mechanism and measure its response.

7. The parts are identified in the text.

8. Before you can trace a circuit from one component to another, you must learn to associate the actual appearance of the part with its symbol in the diagram. Experience is your best guide. The parts list under the diagram will help you get started.

9. Clockwise.

10. Looking from the bottom, pin 1 of an octal tube is the first pin clockwise of the key; pin 1 of a miniature tube is the first pin clockwise of the open space.

11. Recognize the parts, and be able to show how they're wired together.

12. Variable resistors, capacitors, and inductors.

13. A device for changing one form of energy into another.

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14. Hydrophones (in acoustic torpedoes).

15. Algebra and elementary trigonometry.

16. The TMC.

17. Apply an input signal to the circuit. Use an oscilloscope or other test instrument to follow the signal through the circuit, until you find a unit that has the correct input but the wrong output.

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APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

TORPEDOMAN'S MATES (TM)

Quals Current Through Change 11

General Service Rating

SCOPE

Torpedoman's mates maintain, test, repair, and overhaul underwater ordnance such as torpedoes and depth charges used on naval vessels and aircraft; maintain and repair torpedo firing equipment and depth charge release equipment; operate torpedo directors; supervise stowage of underwater ordnance; serve on surface craft, on submarines and tenders, and at aviation activities and repair shops.

Emergency Service Ratings

TORPEDOMAN'S MATES T (Steam/Mechanical Torpedoes), ... TMT

Test, maintain, and repair mechanical torpedoes, tubes, depth charges, and release mechanisms; operate torpedo fire control equipment.

TORPEDOMAN'S MATES E (Special/Electric Drive Torpedoes) ..... TME

Test, maintain, and repair torpedoes (electrically propelled/electronically controlled), tubes, control equipment, and depth charges; test and maintain storage batteries.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see *Manual of Navy Enlisted Classifications*, NavPers 15105 (Revised), codes TM-0700 through TM-0799.

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Qualifications for Advancement in Rating	Applicable Rates		
	TM	TMT	TME
100 PRACTICAL FACTORS			
101 Operational			
1. Demonstrate ability to ready, fire and secure a signal ejector, if aboard a submarine. Know and follow safety precautions	3	3	3
2. Locate and identify torpedo components, parts of torpedo mounts or submarine tubes and depth charge projectors and release tracks by reference to associated drawings and diagrams	3	3	3
3. Demonstrate knowledge of ordnance, high-pressure air, and hydraulic safety precautions	3	3	3
4. Demonstrate ability to operate a voltmeter, megger, and multimeter	2	.....	3
5. Identify electrical symbols used in schematic diagrams of torpedoes and exploder mechanisms	2	2	3
6. Identify electronic component symbols	1	.....	3
7. Operate a torpedo director	1	1	.....
8. Interpret electronic wiring and circuit diagrams found in equipment instruction books	1	.....	2
102 Maintenance and/or Repair			
1. Perform routine for upkeep of fully ready torpedoes, following a checkoff list; identify and demonstrate proper use of tools required	3	3	3
2. Inspect, clean, lubricate, and test depth charge tracts and release mechanisms on own ship	3	3	3
3. Clean, lubricate, inspect, and test-operate a depth charge projector on own ship	3	3	3
4. Perform operational tests and lubrication of a torpedo mount and/or tubes on own ship, following checkoff list	3	3	3
5. Clean, test, charge, remove, and replace torpedo batteries on own ship or station	3	.....	3
6. Charge or boost a torpedo air flask, observing safety precautions	3	3	3
7. Perform routine inspection and maintenance of depth charges on own ship	3	3	3
8. Demonstrate ability to solder	3	3	3
9. Demonstrate ability to sweat a watertight or airtight flange, joint, stud, or lead	2	2	2

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Qualifications for Advancement in Rating	Applicable Rates		
	TM	TMT	TME
102 MAINTENANCE AND/OR REPAIR—Continued			
10. Perform all tube post-firing routine on own ship	2	2	2
11. Perform continuity, ground, and short circuit tests on a torpedo propulsion motor; test a torpedo propulsion motor for RPM; test and adjust a torpedo motor starting switch on own ship or station	2	.....	3
12. Disassemble and reassemble an afterbody	2	2	2
13. Perform preliminary and final adjustments on a torpedo, following a checkoff list	2	2	2
14. Perform torpedo post-run treatment, following checkoff list	2	2	2
15. Identify tools used in preliminary and final adjustments and post-run treatment of a torpedo and demonstrate proper use of each	2	2	2
16. Disassemble, inspect, clean, calibrate, test, and reassemble a control valve	2	2	.....
17. Clean commutators and commutator heads, replace brushes on torpedo rotating electrical machinery, such as motor or dynamotor, on own ship or station	2	.....	3
18. Demonstrate ability to test, disassemble, inspect, clean, and reassemble a reducing and starting valve on own ship or station	1	1	1
19. Perform all electrical and electronic circuit tests of a torpedo; replace parts and adjust and aline components on own ship or station	1	.....	1
20. Disassemble, clean, inspect, reassemble, and test a depth, steering, and torpedo main engine on own ship or station	1	2	.....
21. Test and prepare an exercise head for firing, on own ship or station	1	.....	.....
22. Perform allowable repairs to torpedo gyros and gyro housings on own ship or station	C	C	C
23. Boresight and aline a torpedo mount on own ship	C	C	.....
24. Perform casualty analysis on defective torpedo assemblies and effect repairs or replacements as required	C	C	C

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Qualifications for Advancement in Rating	Applicable Rates		
	TM	TMT	TME
102 MAINTENANCE AND/OR REPAIR—Continued			
25. Install and make allowable tests and adjustments to an exploder mechanism	C	C	C
26. Make authorized tests and repairs to torpedo exploder mechanism test equipment (multimeter-type circuits)	C	C	C
27. Trace electronic circuits and analyze circuit failures of a torpedo on own ship or station	C	.....	1
103 ADMINISTRATIVE AND/OR CLERICAL			
1. Record required information in torpedo logs	3	3	3
2. Prepare naval shipyard or tender work request or job order	2	2	2
3. Maintain underwater ordnance logs and record sheets in current status	1	1	1
4. Direct onloading and offloading of torpedoes	C	C	C
5. Maintain a Current Ship's Maintenance Project (CSMP)	C	C	C
6. Organize work assignments and supervise personnel to accomplish maintenance and repair projects as directed	C	C	C
200 EXAMINATION SUBJECTS			
201 OPERATIONAL			
1. Methods of recovering torpedoes	3	3	3
2. Identification of parts using assembly drawings	3	3	3
3. Types of information shown and meanings of electrical symbols used in schematic diagrams of torpedoes and exploder mechanisms	2	2	2
4. Identification of standard electronic parts symbols used in schematic drawings	1	.....	3
5. Elements of torpedo fire control surface problem	1	1	.....
202 MAINTENANCE AND/OR REPAIR			
1. Operating principles of hydraulic manual release controls for depth charge tracks	3	3	3
2. Methods of testing projector firing circuits; characteristics of projector impulse charges and projector safety precautions	3	3	3

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Qualifications for Advancement in Rating	Applicable Rates		
	TM	TMT	TME
202 MAINTENANCE AND/OR REPAIR—Continued			
3. Characteristics of and safety precautions for handling primers, black powder, detonators, boosters, TNT, and HBX	3	3	3
4. Soldering materials and soldering methods used in torpedo maintenance and repair	3	3	3
5. Types, structure, electrical characteristics of, and maintenance procedures for batteries	3	.....	3
6. Ordnance, high-pressure air, and hydraulic safety precautions	3	3	3
7. RMA color coding systems for resistors and capacitors	2	.....	3
8. Methods and equipment used in electrical tests for continuity, grounds, and short circuits	2	.....	3
9. Electrical and physical characteristics of electric motors and dynamotors	2	.....	3
10. Calculate current, voltage, and resistance in series and parallel circuits containing not more than four elements	2	.....	3
11. Types of depth charges and depth charge pistols; purpose of testing booster extenders and depth charge pistols; methods of laying or projecting depth charges	2	2	2
12. Effects of moisture and salt water on torpedoes and corrective measures required	2	2	2
13. Types of torpedo lubricants and preservatives and proper use of each	2	2	2
14. Principle of operation of trainable torpedo tubes and mounts	2	2	.....
15. Principle of operation of fixed torpedo tubes	2	2	2
16. Principles of operation of gyroscopes and gyro housings and their application in torpedoes	2	2	2
17. Operating principles of steam-type torpedoes	2	2	.....
18. Application of laws of magnetism to d. c. motors and generators	2	.....	3
19. Function of the following in pneumatic systems:			

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Qualifications for Advancement in Rating	Applicable Rates		
	TM	TMT	TME
202 Maintenance and/or Repair—Continued			
19—Continued			
a. Pneumatic gauges	2	2	.....
b. Check valves	2	2	.....
c. Reducing valves	2	2	.....
d. Starting valves	2	2	.....
e. Manifolds	2	2	.....
f. Control valves	2	2	.....
20. Methods of testing resistors, potentiometers, capacitors, transformers, and vacuum tubes	2	.....	3
21. Function of transducers, servo systems amplifiers, relay control circuits, and vibrators in torpedo electronic systems	1	.....	2
22. Calculate phase angle and impedance in a series circuit and a parallel circuit, each containing not more than four elements	1	.....	2
23. Safety features of a pre-enabling circuit	1	.....	1
24. Operating principles of reducing, controlling, and starting valves; method of testing a reducing valve	1	1	.....
25. Construction of a torpedo gyro and gyro housing	1	1	1
26. Application of resistors, potentiometers, capacitors, transformers, and vacuum tubes in oscillating, switching, detector, automatic volume control, rectifier, feedback network, and d. c. amplifier and a. c. amplifier circuits	C	.....	1
27. Purpose and method of alining torpedo mounts	C	C	.....
203 Administrative and/or Clerical			
1. Types of information found in ordnance pamphlets (OP's)	3	3	3
2. Purpose of Torpedo Record Book	3	3	3
3. Precautions in recovery, onloading, and offloading of torpedoes	C	C	C
4. Periodic reports required for underwater ordnance and current records maintained and types of information found in each	C	C	C

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Qualifications for Advancement in Rating	Applicable Rates		
	TM	TMT	TME
203 ADMINISTRATIVE AND/OR CLERICAL—Continued			
5. Types of information found in the following publications: OD, CCL, OHI, OMI, OML, ORDALTS, NavOrd Instructions and Notices, and NavOrd Allowance Lists; type of information found in and use made of NavOrd OD 3000. Purpose and scope of BuOrd Manual as stated in chapter 1.....	C	C	C

300 PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER

Torpedoman's Mates advance to Warrant Underwater Ordnance Technician and/or Limited Duty Officer, Ordnance. As an alternate, Torpedoman's Mates advance to Warrant Mine Warfare Technician and/or to Limited Duty Officer, Ordnance.

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